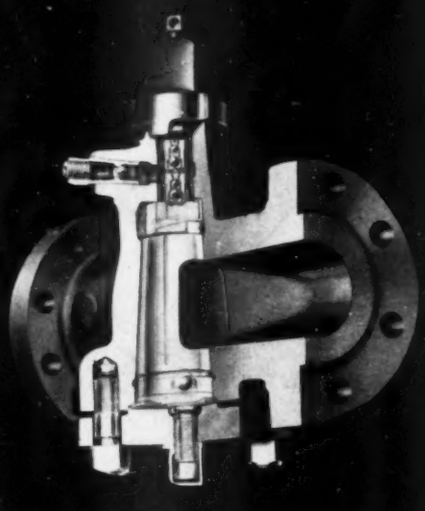
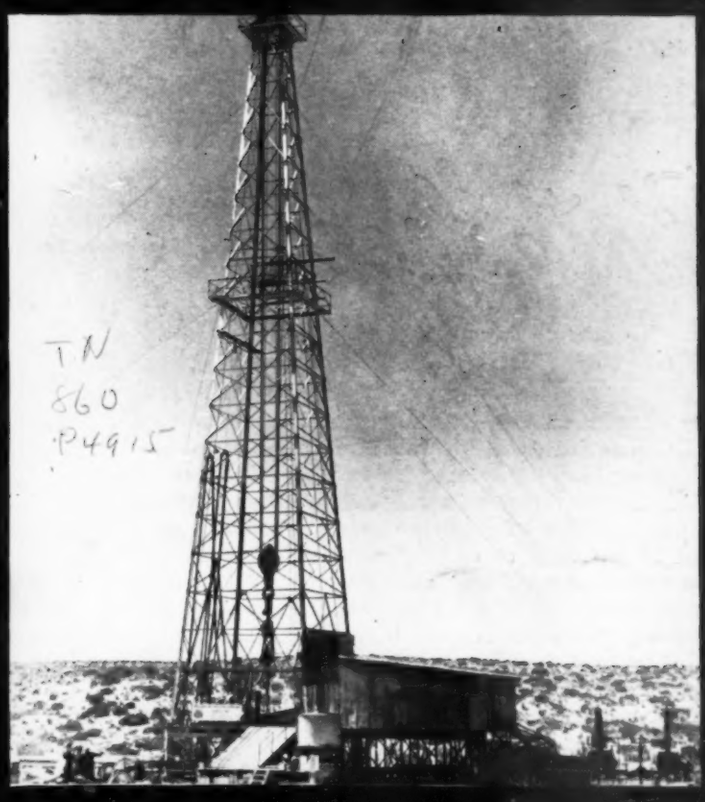
DRILLING
AND PRODUCTION

PIPE LINE

REFINING
NATURAL GASOLINE





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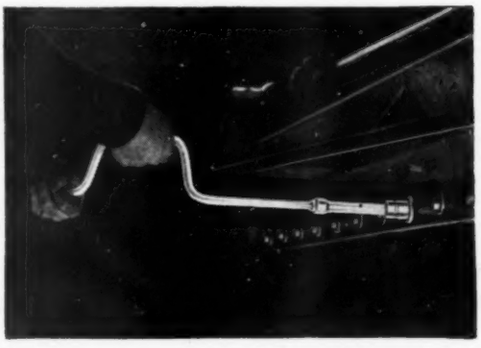

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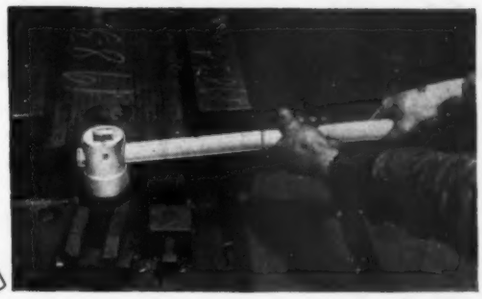

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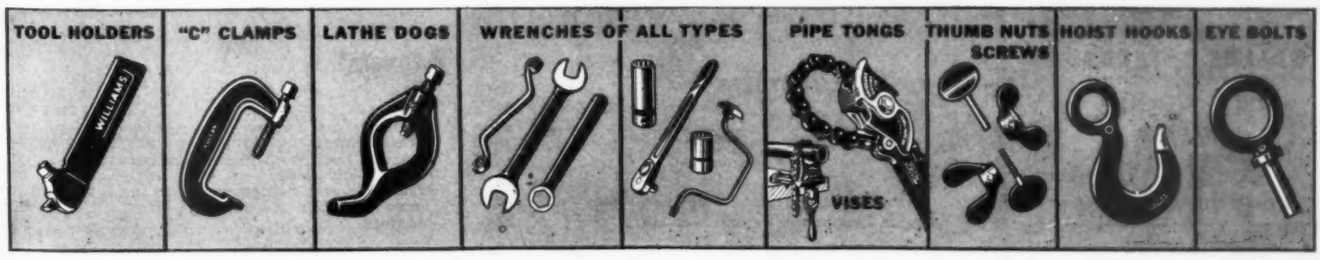

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MEMBER A.B.C.—A.B.P. (The articles in *The Petroleum Engineer* are indexed in the *Industrial Arts Index*, New York, N.

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The new engine you've been hearing about, that will work miracles in performance and economy, hasn't just been waiting the end of the war. It has been waiting development of a piston ring that would stand the tremendously increased mean effective pressures involved, and give the improved anti-scuffing and long wearing qualities required.

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The Course of Oil

by K. C. SCLATER

ROOM FOR COMPETITION

Today the normal vigorous competition of the oil business is largely in abeyance because of the war. This is right and proper. In time of war we must relinquish momentarily the freedom of peace and work together under the direction of unified command. The American oil business is now operating under wartime controls. Prices are fixed and supplies are allocated.

During the war there has been comment on the tendency for small units in the oil industry to sell out to larger units. This is because in some cases it is more attractive for the small operator to sell his underground assets than to produce the oil and sell it.

It is fortunate that the large companies exist so that the small operator can get a fair return on his business by selling it. But this condition certainly does not reflect a desire on the part of the larger companies to eliminate the competition of the small operator. The industry has prospered as one of the most competitive in the world. It will continue to prosper only as it remains highly competitive. And to remain highly competitive, it must attract enterprising capital in the hands of a great many business units—small as well as large.

Some figures will indicate the degree of free competition in the oil business and how important the small operator has been in the business viewed as a whole.

One of the largest American oil companies is Standard Oil of New Jersey. Yet it has only seven per cent of the gasoline sales of oil products in this country. It produces less than ten per cent of the crude produced here. It has under lease only about one per cent of the country's potential oil acreage. Surely, a business in which the largest unit has this proportion of the whole should offer opportunity for the newcomer and plenty of room for competition.

Just before the outbreak of war, the Temporary National Economic Committee issued a study of the oil industry in which twenty oil companies were classified as "majors." This list included Standard of New Jersey, Socony, Texas, Cities Service, Gulf, Sun, Atlantic, and the other nationally known names. It is worth noting that there are as many so-called major companies as that. It is doubtful that in any other basic industry you will find this number. In the automobile industry, in steel, in rubber, there are perhaps half a dozen large-scale competitors. In the oil industry there are twenty.

Among the various divisions of the oil industry—producing, refining, marketing—the only one in which these major companies have a dominant share is that of refining. This is a normal development, because refining is primarily a large-scale and intricate manufacturing operation requiring huge investment in equipment. In refining, the twenty companies designated as majors have about eighty per cent of the country's capacity. Yet, even in refining, the majors are by no means the only factor. It has been reliably estimated that there are 520 manufacturers in the American oil industry.

In the producing phase of the business, the so-called "minor" units account for half of the nation's crude output. They own between sixty-five and seventy-five per cent of all the wells.

Although the terms "major" and "minor" are used to classify companies, actually there is no such clear line of distinction as this implies. Companies in the oil business range through all sizes, with the little ones merging into the big. All of them contribute importantly to the overall picture of our oil economy. The large organizations can do some things more efficiently than the small ones. But it is also true that the small operator can do things that are impractical for the large operator.

Because it brings together the capital of great numbers of people and so has greater resources, the large company can undertake mass production and mass distribution in markets that warrant it. This, of course, results in marked economies for the consuming public. The large company can embark on costly developments, which may take years to consummate and which would exhaust the resources of the smaller man before they began to show a return.

On the other hand, the small operator, using his own capital, responsible to no one but himself, can sometimes assume risks that the directors of a large corporation, as employees of and responsible to a large number of stockholders, may not feel justified in taking.

In this connection it is commonly said in the industry that the majority of United States oil fields have been discovered by small operators. The biggest producing oil field in the world, in fact—the East Texas field—was discovered not by a large company but by a man known affectionately as Old Dad Joiner. Dad Joiner drilled without benefit of geology. He had already sunk two wells, both of which were dry. But he kept moving eastward in Texas, and in 1930, over near the Louisiana border, he made his prodigious find.

Oil is a product of freedom. But wherever there is freedom of action, there is competition. In a sense, competition is a corollary of freedom, and oil is also a product of competition.

Oceans of oil will be needed in the post-war era and we can best get that oil, and best use it, not by giving up but by encouraging initiative and creative activity. This nation needs its great business enterprises—as the record of war production has proved. But it needs the small business as well, so that we may remain a strong, independent, creative people, living together in liberty!

* * *

The foregoing is taken from an address "Oil—Product and Pillar of Freedom" by Eugene Holman, an executive of Standard Oil Company (New Jersey). It merits the attention of all oil men. Oil in all its branches is a highly competitive business, and accounts for the vigor, strength, and independence of the petroleum industry in the United States today; for it is through the stress of free competition that the petroleum industry has prospered, and must continue to prosper after the war, when free competition returns.

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Highlights IN OILDOM

Urge Return of State Oil Powers

Restoration to the states of their regulatory powers over oil and gas production immediately after the termination of the war, and investigation into the federal government's current system of buying up lands and reserving three-fourths of all minerals on those lands as government property, were two of several policies favored by the Interstate Oil Compact Commission at its meeting in New Orleans, Louisiana, this month.

In discussing the former question, Governor Andrew F. Schoeppel of Kansas, chairman of the Commission, declared that "these prerogatives were surrendered upon a temporary basis only for the duration of the war, because a central agency of the government could perform the necessary war duties more quickly.

"The function of conservation should be and must be returned to us immediately upon the termination of the war," Schoeppel said. "We do not propose to accept excuses nor tolerate delays. That which we have freely given up for the war emergency must be promptly taken back when the war is concluded.

"Bitter experience has taught us that it is not always easy to get back from centralized government rights and prerogatives once surrendered," he stated.

"We do not know what the attitude of federal authorities will be when that time comes; but we do know what our position must be and we are determined to maintain it."

Regarding the buying of lands and reserving of minerals by the government, Hiram Dow of New Mexico, presenting the report of the public lands committee of the Interstate Oil Compact Commission, stated that the committee would conduct an investigation into "the federal government's current system of buying up lands and reserving three-fourths of all minerals on those lands as government property." He said the findings of the investigation would be submitted to the senate committee entrusted with the study of America's petroleum reserves.

Dow said the government has already taken up about 500,000 acres of land, and termed this federal project a blow to private enterprise and to exploratory work in the oil industry.

At the closing session of the Compact Commission resolutions adopted included the following:

1. That each state begin promptly the practice of more efficient conservation laws for the purpose of preventing waste and conserving reservoir energy.

2. That each state work toward a reasonable increase in the price of crude oil, and at the same time oppose subsidies on the grounds that they will not solve problems of oil exploration and the need for increased production.

3. That the Commission approves a preliminary report of the National War Council's petroleum advisory committee relative to the need for more oil production.

Government Blamed for Shortage

C. L. Henderson, president of the Western Petroleum Refiners' Association, blamed government officials for the shortage of oil, in an address before the thirty-second annual meeting in St. Louis, Missouri, recently.

"If they had been less concerned with the visionary projects of theorists and relied more heavily upon the sound advice of realistic, experienced oil producers, which would have resulted in an authorization of a reasonable advance in the price of crude oil and refined products, this shortage could have been alleviated," he asserted.

Suppliers' Responsibility Great

Suppliers must continue to carry heavy responsibility for the distribution of petroleum production equipment where it is most urgently needed, War Production Board and Petroleum Administration for War officials emphasized at a recent Petroleum Equipment Suppliers Industry Advisory Committee meeting. Suppliers will be expected to maintain stocks to meet the needs of a greatly accelerated oil production program, they said, but items continue tight, and no possibility of normal inventories can be realized at this time.

Wire rope and internal-combustion engines, both necessary for petroleum production, were described by WPB officials, as being in extreme competition with direct military orders and therefore cannot be expected to be any more readily available at present.

Drill pipe and tool joints, WPB said, are being produced at the limit of industry capacity and are going through a transition period from inadequate supply to a quantity large enough for actual operating needs. Ten million feet of drill pipe and 300,000 tool joints will be produced in 1944, board members said.

Equipment suppliers were given much credit by government officials for their successful refereeing of operator demand with resulting favorable effect on petroleum production. Within the framework of wartime equipment shortages, petroleum production is well on its way to a wartime goal of five million barrels per day, PAW offiicials said.

Says Oil Industry Should Be Unshackled

American car owners would be glad to pay one cent more per gallon for gasoline in order to assure an ample future supply, Maston Nixon, president of the Texas Mid-Continent Oil and Gas Association, said recently in a statement in which he declared that the petroleum industry should be unshackled so that it could drill more wells and produce more oil.

"In the years prior to the war," Nixon said, "the producers of crude oil, operating in an atmosphere charged with incentive—the result of free enterprise—developed the capacity to produce crude oil in such volume that they were able to curtail drilling during the first two years of the war. Thus they contributed their steel to supply the critical needs of the war effort.

"While tremendous expansion took place to build planes, tanks, ships, mobile artillery, and other tools of war, the drilling of oil wells was curtailed to approximately one-half of normal development. Yet it takes the products of crude oil to propel all this material for a mechanized war and on so many fronts. The contribution to the war effort by the producers of crude oil in the United States is unparalleled.

"Now that steel and other materials needed to drill wells are more plentiful, the producers of crude oil should be unshackled so that they may drill when and where in their judgment is best. That their capacity to produce developed long before the war is the best proof of the soundness of this policy.

"At the same time, give to these producers a fair price for crude, based upon increased costs in finding and producing oil. New petroleum reserves and capacity to produce will be the results.

"There is plenty of oil left to be found in this country. It will cost more to find it. The users of gasoline would be glad to pay an added cent per gallon to be assured a future supply.

"This formula for restoring domestic crude oil supply is simple. It will be more effective than subsidies or our government's ventures in foreign oil. This formula should be put into operation at once."

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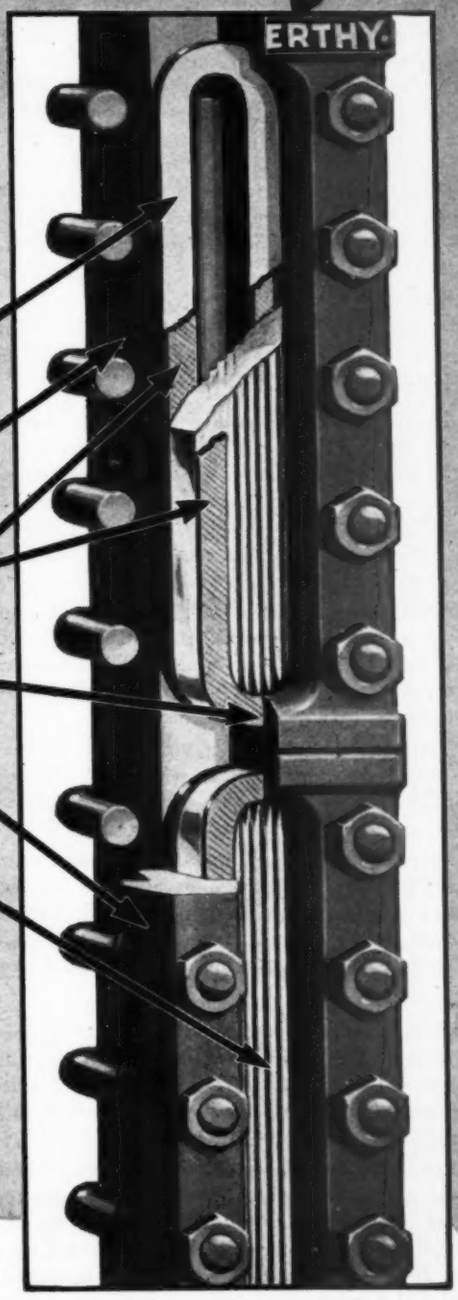

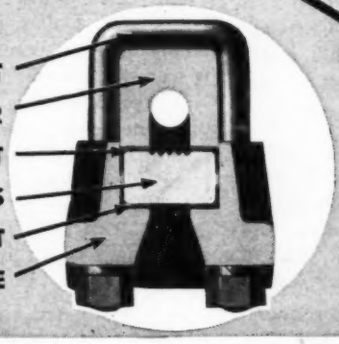

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MAJOR *Pipe Line* ACTIVITIES

THE Kansas-Nebraska Natural Gas Company has applied for authority from the Federal Power Commission to construct and operate 156 miles of natural gas pipe line in Kansas and to install additional equipment in its system. The plan calls for construction of 41 miles of 18-in. pipe line from Hugoton gas field in Kansas to the company's compressor station near Scott City, Kansas; for 100 miles of 12¾-in. pipe line northeast from Scott City, and for 15 miles of 8⅝-in. line the remaining distance to the Stockton compressor station. The application also called for installation of 4 additional 500-hp. compressor units at the Scott City station. Total cost of the plan was estimated at $2,343,000 including $250,000 for the new compressor units.

Principal places of business for the Kansas-Nebraska gas firm are in Phillipsburg, Kansas, and Hastings, Nebraska.

Financing of the big natural gas pipe line to be built by the Tennessee Gas and Transmission Company from Texas to West Virginia is reported to involve a loan of $44,000,000 from the Reconstruction Finance Corporation. The loan is said to be for a period of 10 years with interest at 4 per cent a year. The principal is to be repaid at the rate of $3,000,000 a year, the first installment falling due one year after the line is completed and begins operating.

The 24-in. pipe line will be 1400 miles long, with its Texas terminal near Corpus Christi and the West Virginia terminal at Cornwall Station. It will have an initial capacity of 207,000,000 cu. ft. of natural gas a day.

The Tennessee company owns some gas production in Texas and has contracts to maintain its supply for 30 years, it is said, including contracts with The Chicago Corporation, which owns extensive gas reserves in the Texas fields.

The Hope Natural Gas Company, a subsidiary of the Consolidated Natural Gas Company, and the United Fuel Gas Company, a unit of the Columbia Gas and Electric Corporation system, have contracted to purchase the gas that is delivered to the Cornwall Station for a period of 20 years.

Completion of the 385-mile, 16-in. crude oil pipe line of the Stanolind Pipe Line Company from the Slaughter and Wasson fields of West Texas to Drumright, Oklahoma, where connection is made with the system that goes north to Whiting, Indiana, and other points, is announced.

The line, with capacity of 65,000 bbl. daily, is designed to relieve the crude oil shortage hampering mid-western refinery operations. Holding 483,000 bbl. of crude oil, the line was filled the first of this month and began operating with a delivery of 30,000 bbl., half of which went on north to supply Standard Oil Company of Indiana requirements and the remainder is being tanked. This accumulated storage will be used to supply a 100-car-a-day capacity railroad loading rack Stanolind is building at Cushing, Oklahoma, at the request of PAW to provide facilities for movement of the crude to the East by railroad tank car. The loading rack will be constructed to handle and load 35,000 bbl. of oil daily into tank cars.

This is the second pipe line from the West Texas area to be completed within a short time as a part of the pipe line construction program of the PAW. The 336-mile, 12-in. line from Midland to Corsicana, built by Magnolia Petroleum Company, was placed in operation on March 10. With completion of the Stanolind line to Drumright, 18 of the 24 pipe line projects sponsored by the PAW have been completed and placed in operation.

Application of the Cities Service Gas Company, Bartlesville, Oklahoma, and the Cities Service Transportation and Chemical Company, Ponca City, Oklahoma, for certificates of public convenience and necessity to construct and operate additional facilities has been given a hearing by the Federal Power Commission. An expenditure of approximately $4,000,000 is said to be needed to increase substantially the flow of gas from the Hugoton, Oklahoma, field through the pipe line system that supplies gas for a wide area in Oklahoma, Kansas, Nebraska, and Missouri.

The application asks for additional pumping equipment to step up the capacity of the new 231-mile natural gas pipe line in Oklahoma to 220,000,000 cu. ft. per day by next fall. B. S. Watson, president of the Cities Service Transportation and Chemical Company, which built the line, stated that the two companies would share the cost of construction of new facilities on a 50-50 basis.

A pipe line from West Texas to the Los Angeles area in California to carry crude oil or petroleum products, if needed, is a new project awaiting authority of the Petroleum Administration for War and other agencies. Application has been filed with PAW for priorities assistance in obtaining steel pipe and other materials to construct the 930-mile, 20-in. line by the Pacific War Emergency Pipe Lines, Inc., headed by a group of independent oil producers of West Texas. The plan is to do for the West Coast what the Big Inch and Little Big Inch pipe lines are doing for the East. The oil men contend that before many months the Pacific will become of major importance in the war and steps should be taken now to insure adequate supplies of oil and gasoline on the West Coast.

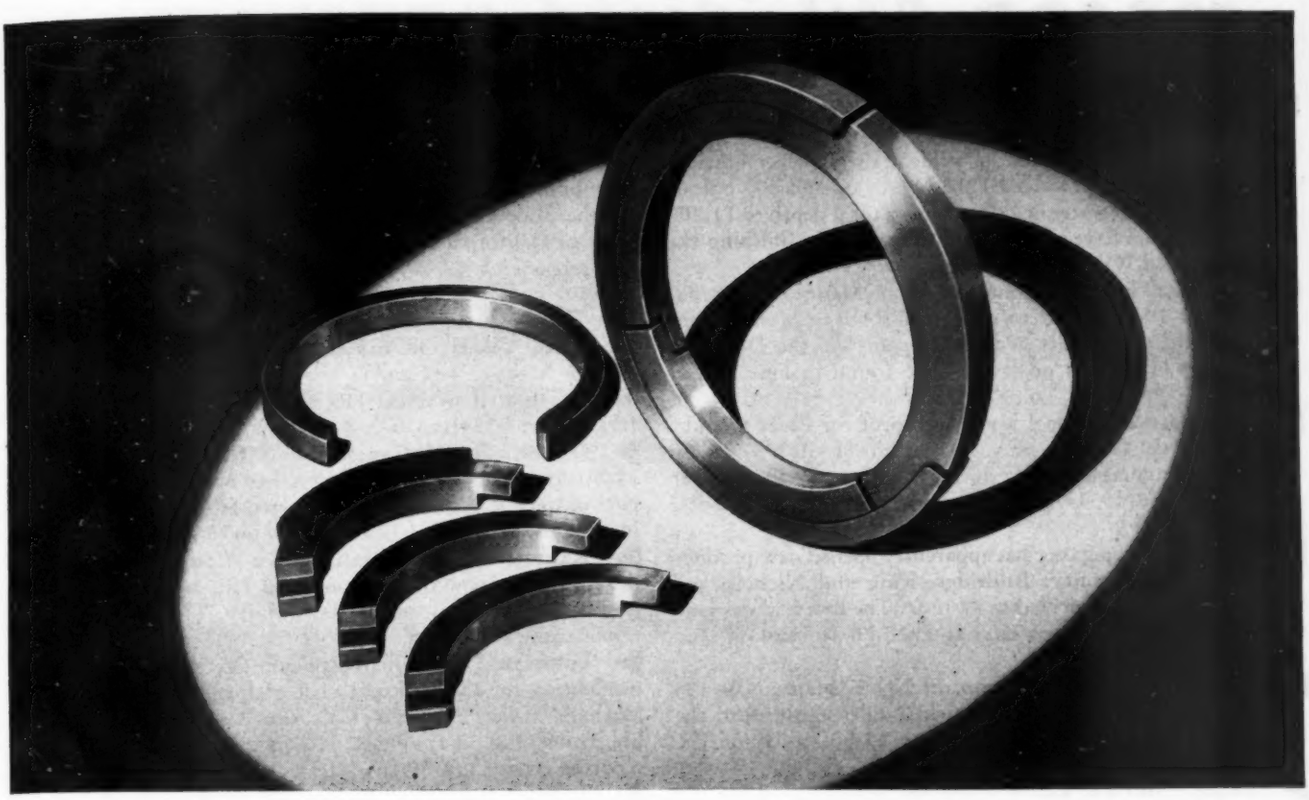
Pacific War Emergency Pipe Lines, Inc., has been incorporated under charter provisions almost identical with War Emergency Pipe Lines, Inc., the corporation that built and is now operating the two pipe lines from Texas to the East Coast. Home office of the new organization is Dallas, Texas. Angus G. Wynne, Dallas, is president; J. C. Hawkins, West Texas oil operator, vice president, and L. M. Glasco, another operator, is secretary-treasurer.

The proposed pipe line would run from Monahans, important pipe line center, along a route north of the Mexican border, passing through or near El Paso, Texas; Deming and Lordsburg, New Mexico; Tucson, Arizona, and crossing the California state line at Yuma, terminate at Beaumont, above the refining district of Los Angeles. From the California terminus, supply lines to the various refinery units can be operated by gravity flow.

It is estimated that construction of the line will require 175,000 tons of steel. Normal capacity would be 180,000 bbl. a day, operating 17 pumping stations. Officials of the company state that the line can be completed and placed in operation 6 months after materials are made available.

The J. R. Horrigan Construction Company, Houston, Texas, has purchased the equipment of J. C. Truman Construction Company, El Dorado, Kansas, and most of the Truman personnel has been added to the Horrigan staff. The latter firm was organized by J. R. Horrigan, who has been in the pipe line construction business since he left St. Mary's College at St. Mary's, Kansas. For the last 8 years he was vice president of Williams Bros. Corporation.

Horrigan is also president of Lake Long Gas Company and Gas Distributing Corporation, Thibodaux, Louisiana. His new construction firm has a contract for 47 miles of Tennessee Gas and Transmission Company's big gas line from Texas to West Virginia.



IMPROVED FIRE CHECKS

FOR DOUBLE-ACTING GAS ENGINE PACKINGS

IN a Double-Acting Gas or Diesel Engine packing, special packing rings are required that will withstand the impact of explosion and the intense heat of the burning gases. These rings are called Fire Checks.

COOK has engineered many style Fire Checks—each of unique construction to meet specific operating conditions. Of these Fire Checks, the styles used most widely in the oil and gas industries are Types RG, OG and K. Type OG is illustrated above. It is shown because it is typical of all three and most readily discloses the simplicity of construction. Note there are only four parts. Note the absence of any screws or rivets in the "lug" ring. Note also that the wearing segments have step-seal joints, thus enabling the use of only one ring per groove.

Type K differs from Type OG principally in the joint construction, having butt cut joints and is therefore used in pairs. But in either case the overall number of rings would be the same.

Fire Checks usually are made of COOK'S GRAPHITIC IRON, although Cookmet sometimes is used if a ring made of plastic bronze is indicated, in which case style RG is employed.

COOK'S improved Fire Checks have been time tested in the field before a general offering, as are all of COOK'S products. Today these improved Fire Checks are being used by leading operators in the natural gas industry everywhere.

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COOK'S METALLIC PACKINGS

MAJOR *Oil Field* ACTIVITIES

▶ **Oklahoma.** Evidence of a big producer has shown in The Carter Oil Company No. 1 Cottingham, CSE SW 4-7-3w, McClain County. A test of the wildcat through perforations from 10,640-50 ft. produced 1215 bbl. of oil and 205 bbl. of basic sediment and water in 28 hr. With a total depth of 11,209 ft., the operators have encountered difficulties in finishing the well for Second Wilcox production.

▶ **Illinois.** The Texas Company No. 1 Marine State Bank, NEC SE 32-10n-3w, northwest of Hillsboro in Montgomery County, held possibilities as a pool opener in the Devonian lime. Shows of oil and no water were found in lime topped at 1991 ft.

▶ **Indiana.** A new pool was in prospect for Posey County at Frontier Fuel Oil Company No. 1 Hill, SE SE SW 18-7s-12w. After favorable results during a drill stem test of Tar Springs sand at 1931-51 ft., the operators set pipe. Total depth is 2776 ft.

▶ **Texas.** A deep gasser has apparently opened new production in Hidalgo County. Baldridge, King and Nichols, and Sohio No. 1 King was drilled to 7500 ft. The hole had gas sand at 6380-48 ft., oil and gas sand at 6920-70 ft., and oil sand at 7110-20 ft.

▶ **California.** Shell Oil Company No. 1 Afana, NW 18-29s-19e, has opened a new shallow field 2 miles southeast of the Kern River field. The well is producing 15 bbl. a day on the pump from 1035 ft.

▶ **Texas.** Gulf Oil Corporation No. 1 Brewer, Benjamin Lee Survey in Wood County, gauged 230 bbl. of pipe line oil on a 24-hr. test, making it a major discovery. Production is from casing perforations at 7990-8015 ft.

▶ **New Mexico.** Oil shows between 4980-5017 ft. in the Permian lime at the Magnolia Petroleum Company No. 1 U-State may open a new pool in the Tatum area of North Central Lea County. The test is in 10-11s-35e.

▶ **Texas.** Prospects of a big pool in Nueces County came with the announcement that Chicago Corporation No. 1 Weil was flowing an estimated 200 bbl. daily from perforations at 10,190-216 ft. West of Corpus Christi, the well is in block 1 of the McBride subdivision.

▶ **Louisiana.** Oil, condensate, and gas are being produced by the discovery well of the Gordon field, Union Oil Company of California No. 1 Edgewood, Beauregard Parish. From perforations at 6767-70 ft. the well flowed 28 bbl. of oil, 808,000 cu. ft. of gas, and 62 gravity condensate.

▶ **Texas.** A new Caddo lime oil pool has been opened by the H. F. Wilcox Oil and Gas Company and others No. 1 George Scaling, J. Gamble survey in Clay County, North Texas. The well swabbed 115 bbl. of oil in 24 hr. from perforations at 5554 ft.

▶ **Illinois.** George Cassons No. 1 Keuhne, NE NW NW 32-8n-5w, Montgomery County, has opened a new shallow pool in the Pottsville sand encountered at 635 ft. While cleaning out the well bailed 12 bbl. of oil in 18 hr.

▶ **Kansas.** Republic Natural Gas Company appears to have opened a new oil pool on Boyd Hill at the No. 1 J. R. Logan, NEC 9-18-14w, Barton County. The well tested approximately 400 bbl. of oil daily from 3333-80 ft. in lime.

▶ **Louisiana.** Magnolia Petroleum Company opened a new production for the Lockport pool with completion of No. 36 Mathilda Miller, 9-10s-9w, Calcasieu Parish. It produced 125 bbl. from 7250-57 ft. and 7264-68 ft. with the oil sand being reported from 7252-79 ft.

▶ **Kansas.** Adair-Morton and others have given Butler County a new oil pool at the No. 1 Craft, in the NWC SW 6-20-11w, 4 miles southwest of the Burgess. The well has been assigned a rating of 196 bbl. of oil daily from the Arbuckle lime at 3345 ft.

▶ **Oklahoma.** A new producing zone for the East Naval Reserve area was uncovered by the No. 3 Lohah, SWC NE 18-24-8e, Osage County. The operators, W. M. Dunn, Carl Porter and Clyde S. Miller, found production in the Arbuckle limestone at 2840 ft. In the first 24 hr. the well flowed 260 bbl.

AVERAGE CRUDE OIL PRICES

California	
Kettleman Hills	$1.23-1.29
Playa Del Rey	.80- .87
Coalinga	.73-1.13
Wilmington	.68-1.24
Montana	1.00-1.15
Wyoming	.45-1.15
Colorado	1.05-1.07
New Mexico	.70-1.15
Texas	
North Central	.97-1.25
Panhandle	.70-1.12
West Texas	.80-1.27
Gulf Coast	.93-1.48
Darst Creek	1.14
East Texas	.80-1.27
Talco	.79
Kansas	.93-1.25
Oklahoma	.75-1.25
Arkansas	.94-1.36
Louisiana	
Rodessa	$ .88-1.20
Gulf Coast	.93-1.36
North Louisiana	.98-1.30
Illinois	1.22-1.37
Kentucky	1.32-1.43
Indiana	.85-1.25
Ohio	
Lima	1.50-1.60
Michigan	1.24-1.44
Pennsylvania	
Bradford	3.00
Southwest	2.65
Eureka	2.59
Buckeye	2.30
Corning	1.31

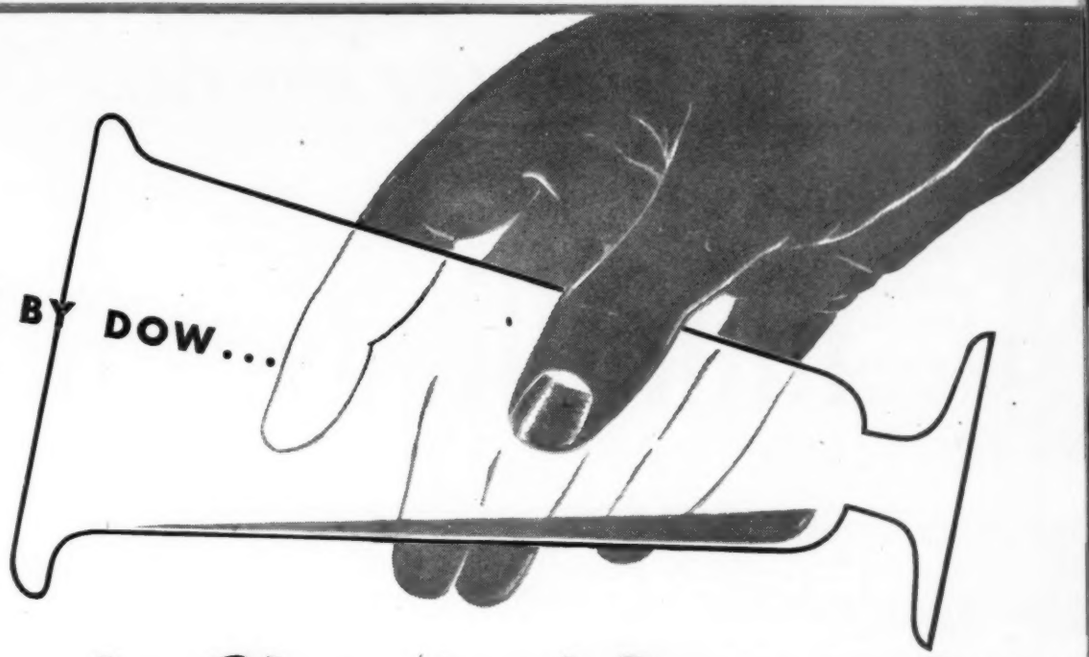
DAILY AVERAGE CRUDE OIL PRODUCTION

Data Supplied by A.P.I.

(Figures in bbl. of 42 gal. each)

	*P.A.W. Recommendations March	ACTUAL PRODUCTION Week ended Mar. 25 1944	Week ended Feb. 26 1944	Week ended Mar. 27 1943
Oklahoma	328,000	329,500	325,400	345,650
Kansas	285,000	274,100	268,050	308,900
Nebraska	1,000	1,350	1,100	2,150
Panhandle Texas	.....	92,850	102,000	88,600
North Texas	.....	142,600	139,950	137,000
West Texas	.....	340,900	362,000	218,100
East Central Texas	.....	116,600	100,250	99,800
East Texas	.....	365,100	390,600	323,400
Southwest Texas	.....	291,500	362,000	173,450
Coastal Texas	.....	513,800	516,600	352,600
TOTAL TEXAS	1,838,000	1,863,350	1,909,650	1,392,950
North Louisiana	.....	76,150	77,200	89,250
Coastal Louisiana	.....	283,950	283,100	250,600
TOTAL LA.	347,700	360,100	360,300	339,850
Arkansas	76,700	79,650	78,750	70,850
Mississippi	46,000	41,500	42,600	53,700
Alabama	.....	50	.....	.....
Florida	.....	50	.....	.....
Illinois	215,000	216,450	211,100	228,200
Indiana	13,600	13,600	12,450	15,950
Eastern	72,200	69,000	68,700	76,150
Kentucky	24,000	22,400	20,100	17,000
Michigan	52,000	50,950	53,500	56,400
Wyoming	93,000	91,350	95,400	91,400
Montana	24,000	20,800	20,950	17,800
Colorado	7,000	8,200	6,900	6,700
New Mexico	111,700	112,850	112,850	92,400
TOTAL EAST OF CALIF.	3,534,900	3,555,250	3,587,800	3,116,050
California	833,400	829,500	796,700	780,200
TOTAL U. S.	4,368,300	4,384,750	4,384,500	3,896,250

*P.A.W. recommendations and state allowables, as shown above, represent the production of crude oil only, and do not include amounts of condensate and natural gas derivatives to be produced.



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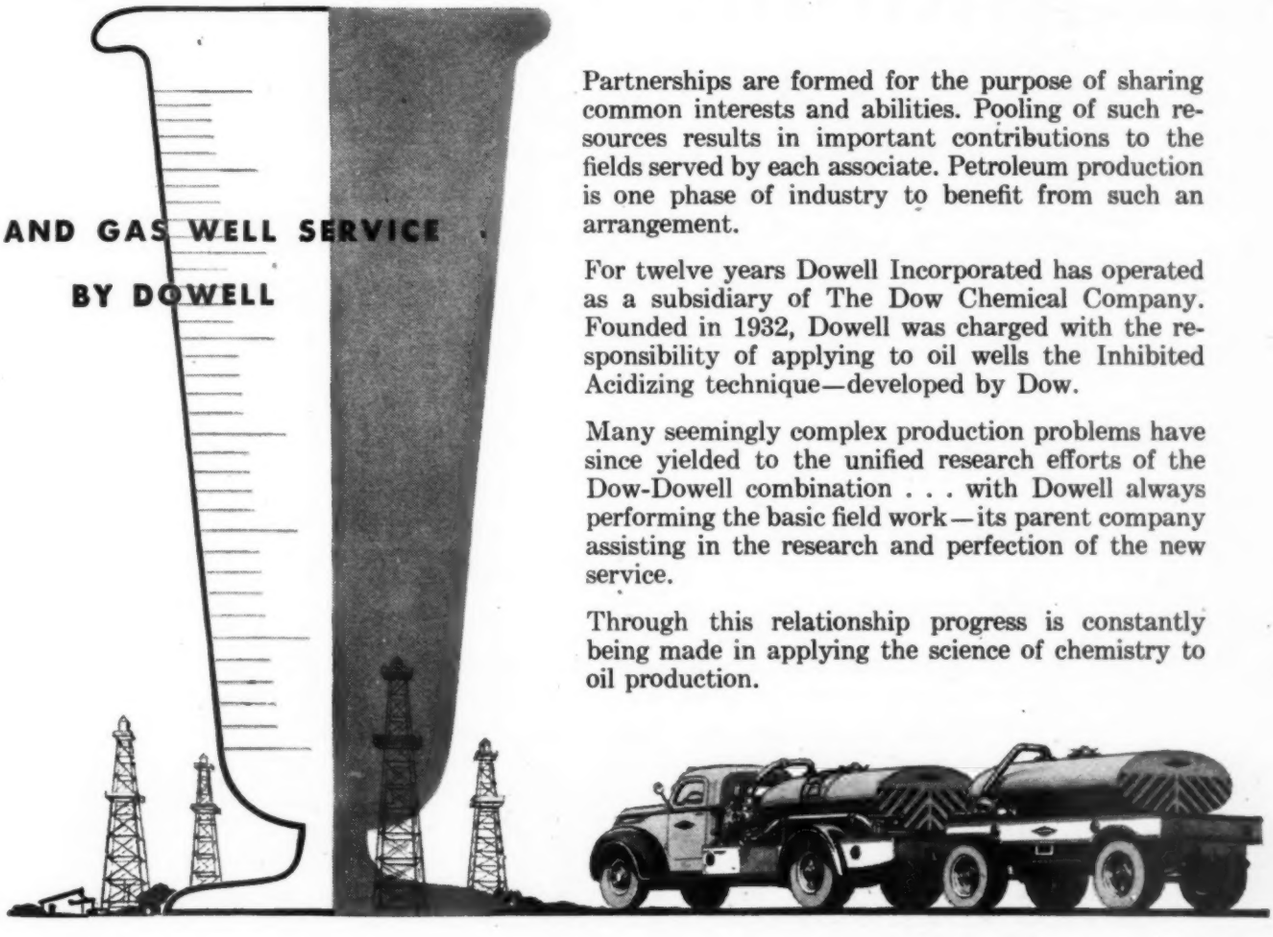

OIL AND GAS WELL SERVICE BY DOWELL

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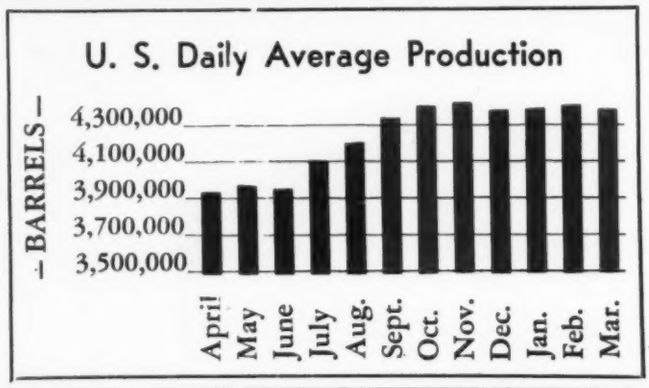
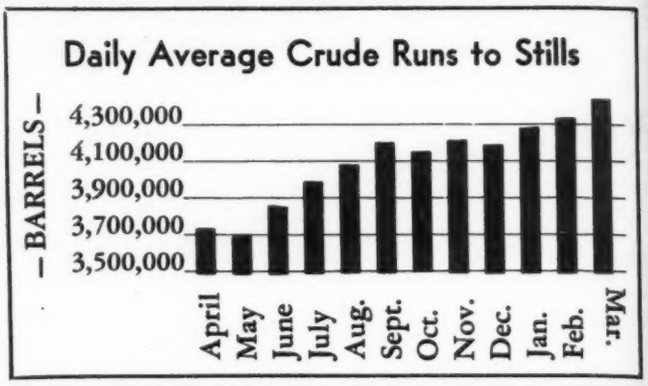
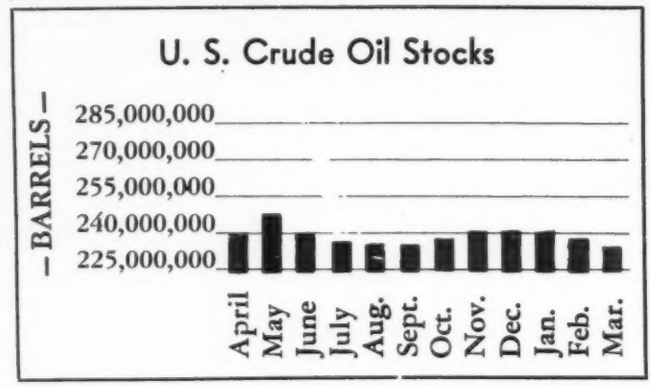
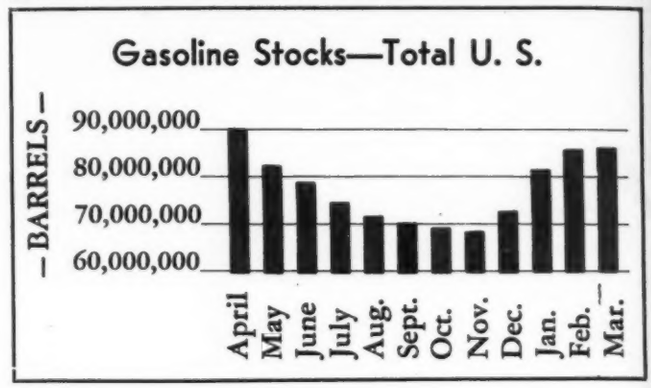
FOR OIL AND GAS WELL CHEMICAL SERVIC

PETROLEUM *Statistics* AND FIELD *Operations*









Above statistics by American Petroleum Institute.

Summarized Operations in Active Fields for March, 1944

Fields	Completions	Producers	Rigs	Drilling Wells	Depth of Production	No. Casing Strings	Gravity of Oil	Type of Tool Used
TEXAS								
Eastern Texas	20	14	13	....	3500-3700	2	40	Rotary
Gaines County	36	21	3	....	4400-5584	2	22-35	Rotary
Hockley County	16	11	9	....	4800-6850	2	20-30	Rotary
Ector County	18	9	8	....	3675-4377	2 or 3	32-36	Rotary
Panhandle	18	14	7	....	1700-3900	2	40	Rot.-Cab.
Nueces County	13	10	11	....	3922-5878	2 or 3	21-54	Rotary
K. M. A. Field	21	11	5	....	3730-3935	2	42-43	Rot.-Cab.
Hawkins Field	9	4	7	....	4495-4912	2	19-29	Rotary
OKLAHOMA								
Okfuskee County	3	6	7	....	2150-4125	2 or 3	38	Rotary
KANSAS								
Russell County	15	12	5	....	2926-3435	2 and 5	32-37	Rot.-Cab.
Rice County	6	3	4	....	3222-4085	2 and 5	42-48	Rot.-Cab.
Barton County	10	6	5	....	3290-3518	2	39-42	Rot.-Cab.
ILLINOIS								
Central Illinois	118	127	95	90	1425-4100	2	36-38	Rot.-Cab.
NEW MEXICO								
Lea County	5	5	3	....	3150-4030	2	30-34	Rot.-Cab.
CALIFORNIA								
Kern County	15	7	7	4	1840-,11450	2 or 4	14-30	Rotary
Wilmington County	11	7	10	13	3500-4000	2 and 3	18-20	Rotary

Field Activities by States for March, 1944

State	Completions		Producers		Locations		Rigs		Drilling Wells		Production, 1943 (bbl.)
	March	February	March	February	March	February	March	February	March	February	
Arkansas	14	18	9	9	11	16	7	7	....	13	27,605,000
California	138	71	106	64	59	60	26	30	16	21	284,415,000
Illinois	156	138	121	126	79	81	80	90	122	103	81,070,000
Indiana	28	40	24	31	33	26	5	6	16	14	5,320,000
Kansas	180	180	132	132	52	50	27	23	25	14	105,780,000
Kentucky	43	51	31	30	21	15	....	....	....	....	7,890,000
Louisiana	42	49	35	34	21	24	....	10	....	16	125,904,000
Michigan	60	51	43	41	31	20	....	11	20	13	20,576,000
Mississippi	4	5	3	3	....	....	....	....	....	....	18,845,000
Montana	21	16	14	7	....	....	7	5	....	....	7,598,000
Nebraska	7	....	5	....	....	3	....	....	....	....	791,000
New Mexico	29	21	25	15	9	11	....	....	....	....	38,955,000
New York	98*	105*	85*	101*	58	49	15	24	....	....	4,783,000
Ohio	55	60	48	49	28	30	14	19	....	....	3,220,000
Oklahoma	130	121	109	93	41	44	....	....	43	46	120,880,000
Pennsylvania	218*	200*	161	170	161	149	....	....	....	....	15,986,000
Texas	360	335	301	274	311	294	210	240	301	290	588,560,000
West Virginia	76	61	72	51	12	22	3	3	14	15	3,256,000
Wyoming	10	8	8	5	1	4	1	3	5	13	34,686,000
Total	1669	1530	1352	1235	925	898	395	471	562	558	1,496,120,000

*Includes water-intake and pressure wells.

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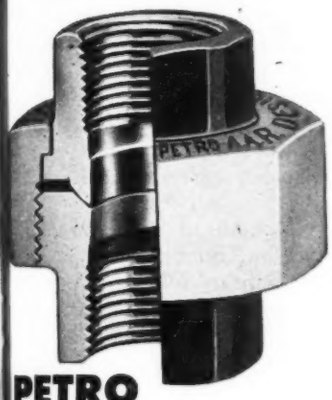
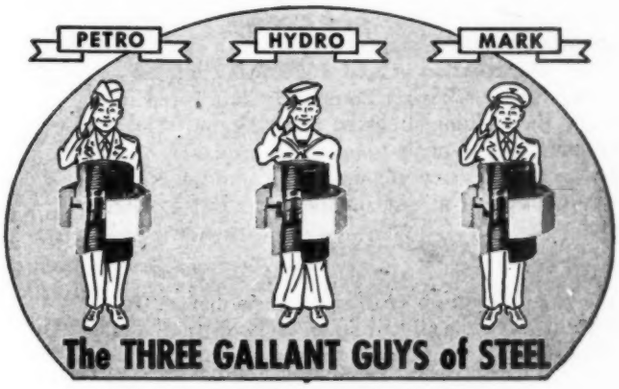


PETRO



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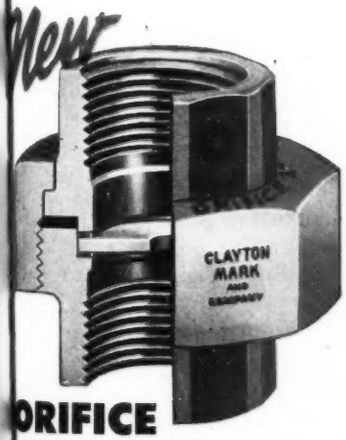

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CONTINENTAL

SERVING THE OIL AND GAS INDUSTRIES

MAJOR *Refining* ACTIVITIES

THE Ohio Oil Company announces that a cycling plant will be erected at Coles Levee, California, to handle 50,000,000 cu. ft. of gas per day. Ohio Oil Company will be the operators and participating companies are Standard Oil Company of California, Richfield Oil Corporation, Union Oil Company of California, and Tide Water Associated Oil Company. The Fluor Corporation, Ltd., Los Angeles, California, are the contractors.

The fluid catalytic cracking unit constructed at Wood River, Illinois, by The M. W. Kellogg Company for the Standard Oil Company (Indiana), has begun initial operation. As is customary in fluid catalytic cracking units, the heated catalyst is continuously fed to a preheated oil stock. The unit was originally designed for motor fuel production and later changed for severe gas oil cracking to produce aviation gasoline stocks.

The unit differs somewhat from the standard Kellogg design in that the reactor and regenerator are supported on skirts from the ground up to gain rigidity, instead of being upheld by the main structure, and in that critical tube and shell heat exchangers were conserved by the use of a pipe coil condenser box for condensing the cracked vapors.

At the peak of construction nearly 1000 men were employed. The two large vessels were completely fabricated in the field. Some of the welding involved plate 2¼ in. thick, and seams were completely x-rayed to insure their quality.

The unit now operating is stepping up American production of the high octane products so vital to the war effort of the United Nations.

Details of the race to develop synthetic toluene before the oncoming war could catch the United States short of this basic ingredient of the explosive, TNT, were made public by Standard Oil Company (New Jersey).

Large scale production of toluene from petroleum began just six weeks before Pearl Harbor at the plant built and operated by Humble Oil and Refining Company, Standard of New Jersey affiliate in Texas.

An article in the company's publication, *The Lamp*, describes how the basic process of hydrogenation brought from Germany in 1927 ultimately proved to be the stepping stone to hydroforming by which toluene is produced.

In making public the history of the development, the company revealed that with war clouds over Europe coming nearer to American shores, the perfection of the process became a race against time in which the U. S. Army Ordnance Department and the company's technologists cooperated.

In seeking to improve petroleum products by hydrogenation, chemists in the Baton Rouge plant of the Standard Oil Company of Louisiana noted that the process produced significant amounts of toluene. By 1933 enough information had been accumulated to present to the Army Ordnance Department. Recognizing an opportunity to avoid the shortage that had plagued them in the last war, the army requested further experimentation.

A year of research resulted in a sample of low-grade toluene that required further purification to produce normal TNT. In 1935 more samples were shipped to the Picatinny Arsenal. This time they were found to be of "nitration grade," but there were still difficulties involved in freeing toluene from impurities.

Four years later, experiments in pilot plants indicated that the solution lay in the type of feed stock. Dozens of stocks were tested before one was discovered that yielded appreciable quantities of toluene. An adaptation of hydrogenation, called hydroforming, produced a product of 99.7 per cent purity. This was merely a laboratory victory, and might prove impossible in commercial equipment. At the army's request, Standard estimated the amount of toluene the new process could produce and offered to build a special plant.

In June, 1940, the army ordered two 10,000-gal. tank cars of synthetic toluene. By that time France was collapsing and there was no time to erect a special hydroforming plant. There was no choice but to shuttle the materials from plant to plant for each successive stage of the process, using whatever facilities were at hand.

A $12,000,000 plant for the production of synthetic toluene was erected for Army Ordnance by Humble at Baytown. Here two-thirds of the country's military toluene was produced in the year following Pearl Harbor. Standard shared the process with the petroleum industry and many new plants have since been put into operation.

The Texas City, Texas, plant of the American Oil Company and its affiliate, the Pan American Refining Corporation, was dedicated last month with proper ceremony. The new fluid catalyst cracking unit, built by M. W. Kellogg Company soars 20 stories high, increasing appreciably production of 100-octane aviation gasoline. It produces enough of this vital fuel to power a 1000 four-engine bomber raid from English air bases to Berlin every week.

Other new facilities include: a sulphuric acid alkylation unit, a new boiler plant to supply steam, a new water station, cooling tower, tankage facilities, and powerful pumping stations. Ten thousand tons of steel and more than 16,000 tons of concrete went into the construction of the giant cat cracker. Thirty-one and four-tenths miles of pipe were installed—in diameters from 2 in. to 72 in.—large enough for a man to walk through.

Crude Runs to Stills, Production[1] and Stocks[2] of Motor Fuels

Week ended March 25, 1944

A.P.I. Figures

(Figures in thousands of bbl. 42 gal. each)

DISTRICT	DAILY REFINING CAPACITY Potential rate	DAILY REFINING CAPACITY Per cent reporting	CRUDE RUNS TO STILLS Daily average	CRUDE RUNS TO STILLS Per cent operated	Total production[3]	Total stocks[3]
*Combined: East Coast, Texas Gulf, Louisiana Gulf, North Louisiana-Arkansas, and Inland Texas	2,518	90.3	2,274	90.3	14,812	107,182
Appalachian						
District No. 1	130	83.9	102	78.5	536	3,492
District No. 2	47	87.2	48	102.1	270	1,585
Ind., Ill., Ky.	824	85.2	763	92.6	4,617	29,826
Okla., Kans., Mo.	416	80.1	363	87.3	2,262	11,523
Rocky Mt.						
District No. 3	8	26.9	10	125.0	67	134
District No. 4	141	58.3	104	73.8	604	3,105
California	817	89.9	779	95.3	5,494	54,990
TOTAL U. S.— March 25, 1944	4,901	87.3	4,443	90.7	28,662	176,737
TOTAL U. S.— March 18, 1944	4,831	87.1	4,437	91.8	28,885	175,864
U. S.— March 27, 1943	.....	.....	3,721	.....	23,158	199,266

*At the request of the Petroleum Administration for War.

[1]Production—total of gasoline at refineries including natural and blended; kerosine, gas, and distillate fuel oil, and residual fuel oil.

[2]Stocks at refineries, bulk terminals, in transit, and pipe lines of finished and unfinished gasoline; kerosine, gas oil, and distillate fuel, and residual fuel oil.

[3]Figures on production and stock include reported totals plus an estimate of unreported amounts and are on a Bureau of Mines basis.

P 501.731.1

THE Petroleum Engineer

APRIL, 1944

The Drowning and Revival Of Gas Wells

☆ Addition of certain liquids to water in gas sands overcomes Jamin action

PART 1

by S. T. Yuster
The Pennsylvania State College

and K. J. Sonney
United Natural Gas Company

Abstract

THE revival of intentionally or accidently drowned gas producing or injection wells is of prime interest to oil and gas producers. Water from leaky casing, excessive coning due to too rapid withdrawals, necessary drowning to control a wild well or make repairs, may all cause an almost permanent harm to a gas well by reducing its capacity. This is not only a problem confronting gas men but is of great interest to oil producers, as gas wells play an important part in cycling operations, pressure maintenance, repressuring projects, and in secondary recovery by air and gas drive. In all these cases the effect of the presence of water is to retard the flow of gas from or into the formation.

A study was made of the problem and it was found to be due to the establishment of a Jamin action. The application of high vapor pressure liquids of low surface tension, which are completely miscible with water, removed the plugging action almost completely. Some of the liquids used with success were acetone and a 9-to-1 mixture of acetone and diethyl ether.

Methods were also developed for the safe drowning of gas wells so that a well could be brought back to production after treatment with very little change in productivity.

Introduction

The revival of intentionally or accidently drowned gas wells is a problem that has confronted gas producers for as long as the industry has existed. The water, which may have come from leaky casing, from other horizons, or from actual injection at the surface for the purpose of controlling a wild well, may build up a head in excess of the formation pressure and penetrate the producing strata. A somewhat similar

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effect is produced when water cones into a gas well and reduces the flow from it. In repressuring projects or in the secondary recovery of petroleum by air and gas drive methods, the entrance of water into the productive horizon at the input wells is very harmful. In all the examples cited the effect of the water is to retard the flow of gas from or into the formation. In some cases the action may be so drastic as to close off flow completely. This effect in the case of a gas producer is not due to a head of water that neutralizes either partially or completely the formation pressure, as pumping the water off the well does not bring it back to its former productivity. Probably the most logical and satisfactory explanation of the phenomenon is that it is probably due to Jamin action.[1,2]

Plugging Action

In order to check this explanation an artificial consolidated sand in the form of a slide (made of sintered grains of Pyrex glass) was drowned with water and the action observed under the microscope. An aspirator bulb was used to force the fluids through the sand. No difficulty was encountered when air alone was flowing through the sand. It was then drowned with water and only a slightly greater pressure was required for flow than with the air. While the sand was still filled with water, air was introduced at the inlet end of the slide and had only penetrated a short distance from the inlet end when the pressure required for further movement had increased to such an extent that it was almost impossible to force in more air with the hand aspirator.

Observation through the microscope showed the air bubbles occupying some of the pores. When pressure was applied, these bubbles attempted to pass through the constrictions between the sand grains. In so doing, it was necessary to distort the bubble considerably. This distortion requires considerable force and, if the breakdown pressure is not exceeded, the bubbles remain in place and hamper the movement of fluids through the sand. In other words, the conducting medium is no longer simply an assemblage of sand grains but must be considered as a complex of solid grains and relatively stationary gas bubbles and water. This phenomenon was first discovered by Jamin, a French physicist, in 1860 and it is known as Jamin action.[1] From the picture given there is little difficulty in understanding why the effective permeability of the sand has been reduced, as some of the channels are blocked to flow. That this

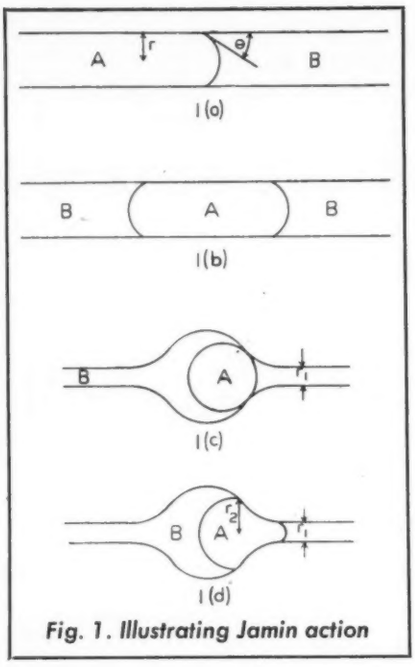


Fig. 1. Illustrating Jamin action

blocking is actually performed by fluids seems fantastic at first thought. The experiments described, however, seem to give adequate support to the belief that the drowning results in a Jamin action that reduces conductivity.

Jamin Action

The phenomenon will be examined in order to understand it more completely and to see the possible methods of attack to overcome the difficulties. As this particular problem is chiefly concerned with the bubble distorting phase of Jamin action it alone will be considered.

Fig. 1 (a) shows two immiscible fluids A and B in a capillary with fluid B showing a greater avidity (or wetability) for the capillary wall than A. Fluid A could be air or any other gas and B might be a liquid such as water. This setup is similar to the capillary rise experiment with the capillary in a horizontal position instead of vertical.

The surface tension of a liquid or the interfacial tension between two liquids may be defined as the force in dynes that must be exerted along one centimeter edge of the surface in order to maintain it in a given equilibrium position. In other words, it is the tensile strength of the surface and will be designated by the letter T. In Fig. 1 (a) the length of the contact line between fluids A and B and the capillary wall is $2\pi\pm$ on the circumference of the tube. As this edge of surface requires that a force of T dynes shall be exerted along each centimeter of its length in order to maintain it in a given equilibrium position, the total force is equal to $2\pi rT$.

This is true only if the force acts in the direction the surface makes with the capillary wall. This direction is designated by θ, the contact angle of fluid B when in contact with fluid A and with the solid of which the capillary wall is composed. In order to obtain the magnitude of the force that must be applied along the axis of the tube, the above expression must be multiplied by $\cos\theta$. The force exerted along the axis of the capillary by fluid B in displacing A, or the force that must be applied through A to prevent B from displacing it, is equal to:

$$F = 2\pi rT\cos\theta \quad \ldots\ldots\ldots\ldots 1$$

As pressure is equal to the force per unit area, the pressure necessary to maintain equilibrium should be equation 1 divided by the cross-sectional area of the capillary or:

$$P = \frac{2T\cos\theta}{r} \quad \ldots\ldots\ldots\ldots 2$$

If two such surfaces are present in a capillary with equal contact angles as

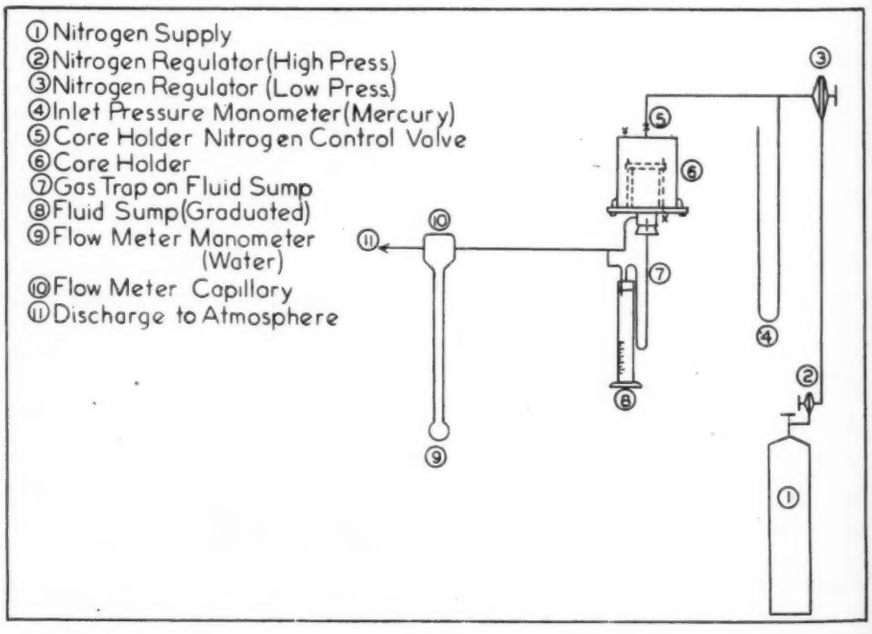

① Nitrogen Supply
② Nitrogen Regulator (High Press.)
③ Nitrogen Regulator (Low Press.)
④ Inlet Pressure Manometer (Mercury)
⑤ Core Holder Nitrogen Control Valve
⑥ Core Holder
⑦ Gas Trap on Fluid Sump
⑧ Fluid Sump (Graduated)
⑨ Flow Meter Manometer (Water)
⑩ Flow Meter Capillary
⑪ Discharge to Atmosphere

Fig. 2. Diagram of apparatus for gas well reviving

is shown in Fig 1 (b), there would be no tendency for displacement as the two pressures involved are equal and opposite.

The capillaries making up oil or gas sand, however, are not as simple as those considered up to this point. Their size and shape vary greatly and they are intimately interconnected.

A portion of a highly idealized capillary is shown in Fig. 1 (c) with fluids A and B in it. If an attempt is made to force fluid B through this system, fluid A will begin to enter the constriction of the capillary as is shown in Fig. 1 (d). Let r_1 and r_2 be respectively the radius of contact of the two fluids and the solid at the smaller and larger ends. Then:

$$P_1 = \frac{2T \cos \theta}{r_1}$$

$$P_2 = \frac{2T \cos \theta}{r_2} \quad \ldots\ldots\ldots\ldots 3$$

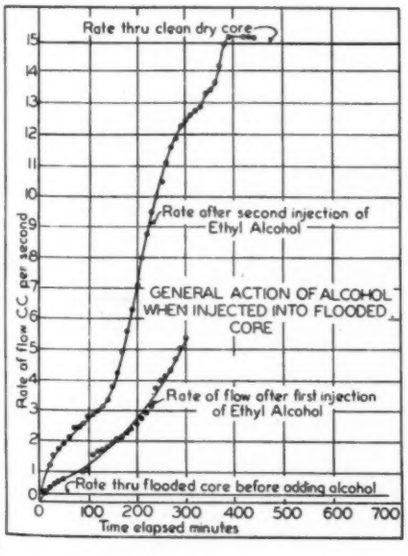
These pressures neutralize one another somewhat and the resulting resisting pressure is their difference or:

$$p = P_1 - P_2 = 2T \cos \theta \left(\frac{1}{r_1} - \frac{1}{r_2}\right) \quad . 4$$

When a small amount of pressure is first applied to B in the system shown in Fig. 1 (c) r_1 is not very much smaller than r_2. As the pressure is increased, r_1 becomes progressively smaller and at a greater rate than r_2 is decreasing.

From Fig. 1 (d) and equation 4 it can be seen that P, the resisting pressure, will finally reach a maximum. It is at this point that the Jamin action will break down and the bubble will pass through the constriction. If this maximum is not reached, the bubble can remain in position indefinitely and oppose any flow through the particular channel. If the maximum is exceeded by only a very small amount, the bubble will move and in passing from a constriction to an expansion in the cross-section of the capillary, a negative resisting pressure will be created. In other words, the bubble in this position will actually aid the flow of fluids.

Fig. 4. General action of alcohol when injected into flooded core



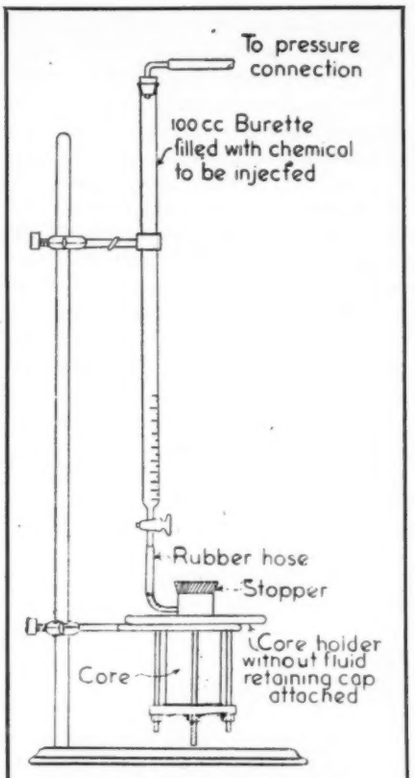


Fig. 3. Method of chemical injection into core

Up to this point consideration has been given to a single constriction and bubble. If there are n of these in a length of sand L, the resisting pressure per unit length will be:

$$\frac{P}{L} = \frac{2\,nT \cos \theta}{L}\left(\frac{1}{r_1} - \frac{1}{r_2}\right) \quad \ldots\ldots 5$$

If it is assumed that the contact angle θ is zero, equation 5 becomes

$$\frac{P}{L} = \frac{2nT}{L}\left(\frac{1}{r_1} - \frac{1}{r_2}\right) \quad \ldots\ldots\ldots 6$$

With the parenthetical expression at a maximum $\frac{P}{L}$ gives the breakdown gradient for the Jamin action.

The surface tension of water T is a function of temperature and, therefore, the magnitude of the Jamin action is affected by the depth of the formation. Values of T versus temperature are listed in Table 1.

It is of interest to substitute some hypothetical values in equation 6 in order to determine the order of stability of this effect. Let $r_1 = 0.01$ cm., $r_2 = 0.02$ cm., $T = 72$ dynes/cm., and $n = 25$/cm. Then $\frac{P}{L} = 80$ lb. per sq. in. per ft. If the Jamin action is in operation over a distance of 10 ft. under the conditions given above, it will be a total applied pressure of 800 lb. per sq. in. to break it. As an actual sand is made up of capillaries having a wide range of sizes, some of the smaller size channels may retain their Jamin plug even though the breakdown gradient has been exceeded for the larger ones.

Table 1
Effect of temperature on surface tension of water, equation 4

°C	T	°C	T
0	75.6	30	71.18
5	74.9	40	69.56
10	74.22	50	67.91
15	73.49	60	66.18
18	73.05	70	64.4
20	72.75	80	62.6
25	71.97	100	58.9

Methods of Attack

An examination of equation 6 will indicate the possible methods of attack on the problem of reviving drowned wells. Applying pressure gradients above that necessary for a breakdown of Jamin action is a possibility, but, as this is only controllable from the well side, (the sand pressure is approximately constant) it will only apply to gas injection in wells in low pressure gas producing formations. According to equation 6 a lowering of the surface tension T of the water in the sand should lower the breakdown gradient. Work on the surface tension of solutions of various compounds has shown that the surface tension is only lowered to approximately 30 dynes/cm. with the most efficient surface modifiers. This would reduce the breakdown gradient by the ratio of $\frac{30}{72}$ or to 0.417 of the original. Even though the breakdown gradients are usually quite high, reducing them by this factor may well bring them into the range where it would be practical to apply pressures to break the plug. It is felt that this would be the exception, however, rather than the rule.

As Jamin action cannot exist unless two immiscible fluid phases are present the removal of one of the phases should eliminate the plugging. If the water could be removed from the sand by some means or another the difficulty would be eliminated. It should be possible to do this by adding some fluid to the water, which is miscible with it in all proportions and which has a high vapor pressure. The condition of complete miscibility is necessary in order not to create any new Jamin action. A high vapor pressure fluid when added to water produces a solution that has a higher vapor pressure than the original water. Under such conditions the rate of evaporation of the liquid will be

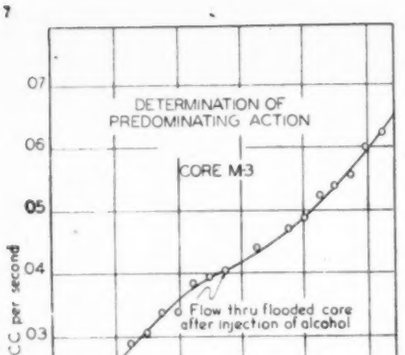


Fig. 5. Determination of predominating action

more rapid than with pure water alone and the Jamin action should be gradually eliminated as gas passes through the region. The high vapor pressure fluids usually decrease the surface tension of the water, which is another favorable factor.

From the foregoing discussion it can be seen that the methods of attack on the problem fall into the following subdivisions:

1. **Removal of water from the vicinity of the well bore by increasing the pressure differential between the well bore and the formation to overcome the Jamin action and force the water ring far into the sand where its thickness and effectiveness in plugging will be greatly reduced.**
2. **Reducing the surface tension of the water in the sand and thereby decreasing the pressure necessary to move the water.**
3. **Dilution of the water in the sand with water-miscible high-vapor pressure solvents resulting in a more volatile fluid mixture that may be removed by evaporation.**
4. **Combination of the above methods.**

With the above possibilities in mind a series of experiments was made in the laboratory to test their practicability.

Apparatus Used

The apparatus was essentially a system whereby gases and liquids could be made to flow radially through a cylinder of sandstone under various pressures. The experimental setup is shown in Figs. 2 and 3. Nitrogen gas was used in the tests as it is inert, convenient, and safe. A high pressure regulator reduced the tank pressure to approximately 15 lb. gauge, and a second regulator further reduced it to the pressure selected for the test. The pressure was measured by a mercury manometer. From the low pressure regulator the gas was admitted to the core holder through a needle valve and passed radially through the core from the outside toward the center. A graduate connected to the outlet of the core holder through a fluid sealed trap served to measure liquid that came through or from within the core. The graduate and the outlet end of the core holder were connected through a T-tube to a capillary flowmeter that measured the rate of flow of gas coming from the core. The flowmeter was provided with several calibrated capillaries that permitted a considerable range of flow rates to be very accurately measured. The entire apparatus was in a constant temperature chamber maintained at 20°C.

Four diamond drilled cores from the Bradford sand were used in the experiments. They had previously been extracted with butanol to remove the oil and water; placed in an electric oven at 105° C. for 15 hr., and finally cooled in a desiccator. The characteristics of the cores are given in Table 2.

apparatus the various chemicals could be injected at any desired pressure from the center of the core radially outward as would be necessary in applying them in the field. When an injection was made, the operation was carried on until there was evidence of the liquid coming out of the core as was determined by the first appearance of liquid on the outside of the core. As soon as the injection was completed, the core was removed from the holder, reweighed, quickly replaced into the coreholder and inserted into the pressure pot. Gas was then passed through the core and the effects of the injection noted.

All flow readings were taken at 5-min. intervals. Weights were recorded to the nearest 0.1 gram. At the end of each run in which only purified volatile chemicals had come in contact with the core, the core was placed in an electric oven at 105°C. for several hours and cooled in a desiccator. If impure chemicals had been injected the core was first extracted before being placed in the oven.

Table 2

Core No.	Core dimensions, cm. O.D.	I.D.	Ht.	Porosity, %	Permeability, md.
M-3	5.67	1.73	6.77	20.0	30.5
M-9	5.60	1.68	6.71	20.0	34.5
LH-5	5.61	1.73	7.17	16.8	16.8
LH-10	5.65	1.70	7.18	15.2	6.2

Experimental Procedure

General procedure in making unplugging tests was to place a previously weighed core in the coreholder, and with the core in place but without any gas flowing, distilled water was run into the holder through a hose connected to the water filling cock.

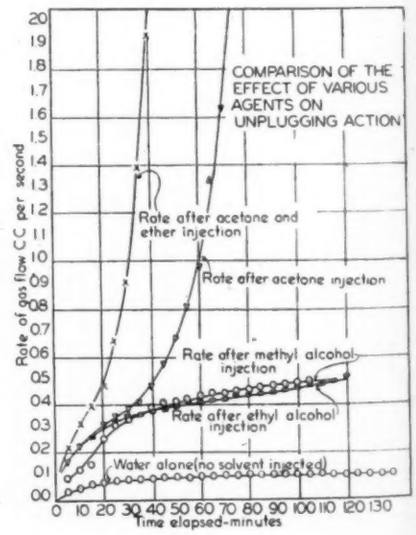
After a coreholder was filled with water the valves were closed, and nitrogen under pressure was admitted to the pressure pot, thus forcing water through the core. Water was passed through the core until the rate of flow became constant as determined by readings of the quantity of liquid collected in the graduate at 5-min. intervals. When the core had been flooded, it was removed, weighed, and then replaced in the coreholder from which the water had been removed. The gain in weight of the core represents the amount of water it took up during the drowning process. Gas was then passed through the core until the rate of gas flow became fairly constant. The core was again removed from the holder and weighed. The difference between this weight and the dry weight gives the amount of water in the sand prior to treatment with an unplugging compound.

For the unplugging treatment, the core was clamped into the coreholder, but was not inserted into the pressure pot. The coreholder was inverted and connected to a burette as shown in Figs. 2 and 3. With this arrangement of the

Unplugging Tests

In order to investigate the general nature of the action of volatile water-miscible liquids on the Jamin plug the following were used in a series of experiments: ethyl alcohol, methyl alcohol, acetone, 9:1 acetone-ethyl ether mixture, and crude methanol. These substances have a fair range of vapor

Fig. 6. Comparison of the effect of various agents on unplugging action



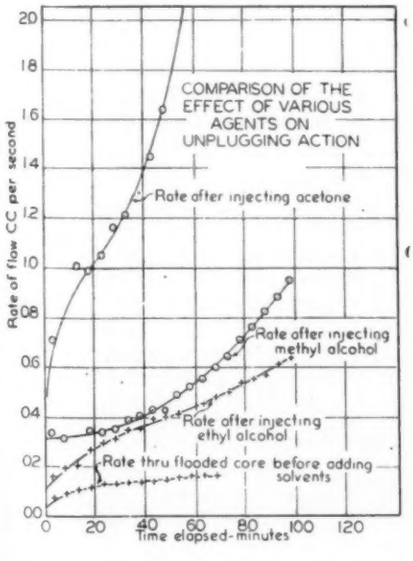
pressures and should evaluate the effect of this factor on unplugging. A 1 per cent solution of IgeponT, a wetting agent, was also used in order to study the effect of the lowering of surface tension as separate from vapor pressure increase.

In the first experiment core M-3 was flooded with water, subjected to a gas flow until a fairly constant rate was obtained, and finally ethyl alcohol was injected in the same manner as the water —from the outside toward the center of the core at 200 mm. Hg pressure. As soon as the first few drops of liquid came through the core the injection was stopped. Measurement of the surface tension of this collected liquid showed it to be nearly all water. Fig. 4 is a graphical summary of this experiment. The line parallel to the x axis gives the rate of flow of gas through the water containing core prior to alcohol injection. This is about 1/60th of the rate when no water is present.

After alcohol was injected, the liquid in the core contained 19.6 per cent alcohol and 80.4 per cent water. The rate of gas throughput as a function of time for the first alcohol injection shows how remarkably the rate picks up after treatment. The second alcohol injection produced an even more rapid return to the original behavior when the core was dry. In fact, the rate after treatment seems to be a bit above the original. In this instance, the single injection would very likely have been sufficient if it had been carried to its endpoint.

Pore space filled with water after the drowning was 72.5 per cent. After flowing gas through this drowned core for some time 46.4 per cent of the pore space remained filled with water. Of this water removed, 76.5 per cent of it was collected as liquid in the receiver

Fig. 7. Comparison of the effect of various agents on unplugging action


COMPARISON OF THE EFFECT OF VARIOUS AGENTS ON UNPLUGGING ACTION
Rate after injecting acetone
Rate after injecting methyl alcohol
Rate after injecting ethyl alcohol
Rate thru flooded core before adding solvents
Rate of flow CC per second
Time elapsed-minutes

and the remaining 23.5 per cent was removed as a vapor by the gas passing through the core. In most of the experiments, the recovery of liquid water was even higher than this with smaller quantities being taken off by the gas. This would indicate that the gas does not readily vaporize the water in the sand. If sufficient time were allowed, however, the gas should remove the water. This depends on the quantity of water in the sand and the available gas. It might not be economic to do it in this manner.

When the gas is allowed to flow through the sand after injection of the volatile liquid, the fraction of the removed liquid that is collected as liquid is of the order of 25-30 per cent. This is considerably lower than when water alone is in the core and shows that one of the effects of the added liquid is to aid in the removal of the water as vapor.

Comparisons

In order to isolate the effect of surface tension alone on the unplugging, a 1 per cent solution of Igepon T was used for treatment. This solution has a surface tension of approximately 30 dynes/cm. as compared to 72 for water at room temperature. The vapor pressure of this solution should not be too far from that of water so the effect of this factor is eliminated. The results of this test are summarized in Fig. 5.

It can be seen that the lowering of the surface tension has only had a slight effect on the Jamin plug. The same graph shows the effect of alcohol for purposes of comparison. The alcohol has a very beneficial effect and it appears, therefore, that the predominating factor is the raising of the vapor pressure rather than the lowering of the surface tension, as both substances lower surface tension but only alcohol raises the vapor pressure.

Vapor Pressure

As an increase in vapor pressure seems to be a necessity for a good unplugging action, the effect of this factor was studied by treating a core with ethyl alcohol, methyl alcohol, acetone, and an acetone-ether mixture containing 10 per cent ethyl ether. The vapor pressures of these liquids in cm. of Hg at 20°C. are, respectively, 4.5, 8.9, 18.0, and 20.5. The last value was estimated from Raoult's law. The vapor pressure of water at the same temperature is 1.74 cm. Hg.

Fig. 6 gives the results of these tests and with the exception of the peculiar behavior of methyl and ethyl alcohol, the rate of the unplugging action seems to vary as some direct function of the vapor pressures of the treating liquid. The acetone and acetone-ether treatments are especially gratifying. Fig. 8 is

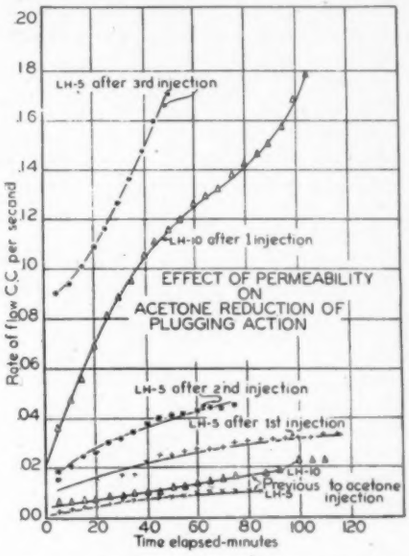


Fig. 8. Effect of permeability on acetone reduction of plugging action

a summary of the data on a check run showing the effect of vapor pressure using a different core. The injection pressure for the treating liquids was 200 mm. Hg as compared to about 37 mm. Hg for the previous run. The results in this second experiment are comparable to the first run and the alcohols line up according to their vapor pressures.

Permeability

As the lower the permeability of a sand the smaller the capillary size, equation 6 predicts that Jamin action will be most marked—that is, the breakdown pressure gradient would be greatest—in a low permeability sand. This is because a smaller capillary size means a larger value for the parenthetical expression in equation 6. In addition to this, n will also be greater in a low permeability sand because of the larger number of constrictions and expansions in a given length of capillary.

Fig. 8 shows the results obtained when acetone was injected into each of the two lower permeability cores after drowning with water. Unfortunately it was necessary to run LH-10 at a pressure of 400 mm. Hg because the rates of flow were so extremely small at 200 mm., the standard pressure in these experiments, that it was impossible to measure the rate with the flowmeter. It will be noted that it was necessary to give core LH-5 three injections of acetone to obtain a rapidly ascending rate curve. The effect of permeability on the unplugging action can be seen by comparing the rate curve for LH-5 (permeability 16 md.) after the first acetone injection in Fig. 8 with the acetone injection curves in Fig. 6, core M-9 of 34 md. permeability, and Fig. 7, core M-3 of 30 md. permeability. It can be seen that for a given elapsed time the un-

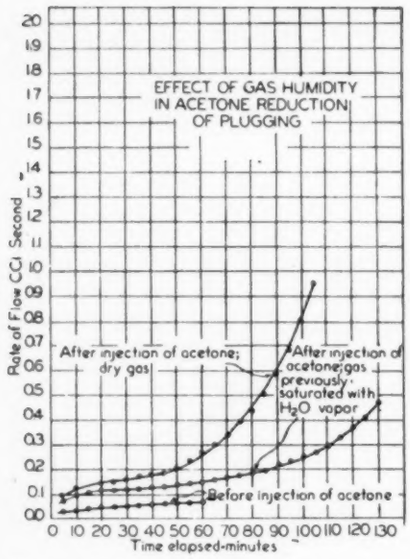

EFFECT OF GAS HUMIDITY
IN ACETONE REDUCTION
OF PLUGGING
Rate of Flow CC/ Second
After injection of acetone; dry gas
After injection of acetone; gas previously saturated with H_2O vapor
Before injection of acetone
Time elapsed-minutes

Fig. 9. Effect of gas humidity in acetone reduction of plugging

plugging action is much more marked in the higher permeability core.

These curves seem to show that for tighter sands, especially when the pressure gradient is low, more than one injection of treating liquid is necessary, whereas with higher permeabilities or greater pressure gradients one injection may be sufficient. This statement is borne out by the fact that LH-5 with a permeability of 16 md. when run at a pressure of 200 mm. Hg required three injections of acetone and LH-10, having a permeability of only 6 md., required only one injection when run at 400 mm. pressure.

Gas Humidity Effects

In some cases in the field the gas may contain an appreciable amount of water vapor and it is important to know what effect it will have on the unplugging action. Fig. 9 shows the results of a test made with core M-9 in which the gas passing through the core had been previously bubbled through distilled water and was, therefore, in a saturated condition before entering the sand. The curves show that the moisture free gas will take on more water than one already containing water vapor. Nevertheless, even though the gas does contain considerable moisture, it still has a capacity for removal of the solution from the sand. This is perhaps chiefly due to the sharp pressure drop in the immediate vicinity of the well, causing the gas to expand and giving it a greater capacity for moisture than it would have at the higher pressure at a distance from the well.

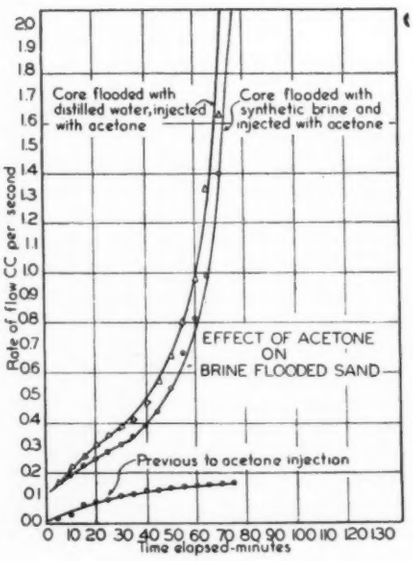
Salt Water Effects

In many cases the drowning action on gas wells is due to the penetration of connate water into the producing horizon. Consequently the effect of the dissolved salts in the water on the results of an unplugging treatment should be known. As acetone and methyl and ethyl alcohol have an unlimited solubility in water, whereas salts of the type found in connate water have a limited solubility in water and a still lower solubility in alcohol-water or acetone-water solutions, there may be a precipitation of salt when acetone or alcohol is added to a brine.

A 30 cc. sample of a synthetic gas field brine was titrated with acetone previous to flooding the core with this particular brine. It was found that 9.4 cc. of acetone were required to start the precipitation of the dissolved salts. Fig. 10 is the plotted data obtained from treating a brine flooded core (M-9) with acetone compared with similar data for the same core flooded with distilled water. It appears that so far as the general action is concerned, acetone unplugs a brine flooded core as effectively as it does a water flooded core; however, as the process is chiefly one of evaporation, it is reasonable to expect that whatever salts are in solution in the drowning water will remain as a deposit in the sand after evaporation of the water. Therefore, some decrease in permeability should take place.

Previous to flooding with salt water, the core had a permeability of 34.4 md., whereas after flooding and evaporation of the water, the permeability had decreased to 28.0 md., a decrease of 24.4 per cent. As precipitation of salts takes place when brines are mixed with alcohols or acetone, it is to be expected that there will be an increased resistance to the displacement of liquids as such and a somewhat further retardation of the unplugging process.

Fig. 10. Effect of acetone on brine flooded sand


Core flooded with distilled water, injected with acetone
Core flooded with synthetic brine and injected with acetone
EFFECT OF ACETONE ON BRINE FLOODED SAND
Previous to acetone injection
Rate of flow CC per second
Time elapsed-minutes

Movie Stars Back Wildcat

There are all kinds of people in the oil business and now a bit of glamour has found its way in, adding to the heterogeneous mixture. According to report, Miss Arlene Judge and Charles Butterworth are financing a wildcat in southern Pottawatomie County, Oklahoma.

Ralph Stone, a car dealer of Las Vegas, Nevada, is associated with the two stars and their venture is the No. 1 Ball, NE NW NE 9-5n-3e. Scribner and Beebe, contractors of Okemah and Tulsa, are drilling the wildcat.

Natural Gas vs. Nitrogen

Nitrogen was used in all these experiments for the sake of convenience and safety. The gas that is actually involved in the problem, however, is natural gas. In order to determine the difference in behavior between the two gases some tests were run. Fig. 11 shows the results of the work. Not only does natural gas show a more rapid response to treatment but in addition the Jamin action was not so intense in the drowned sand. No explanation has been found for this difference but it may be due to the higher solubility of methane in water than nitrogen and the lowering of the surface tension of water.

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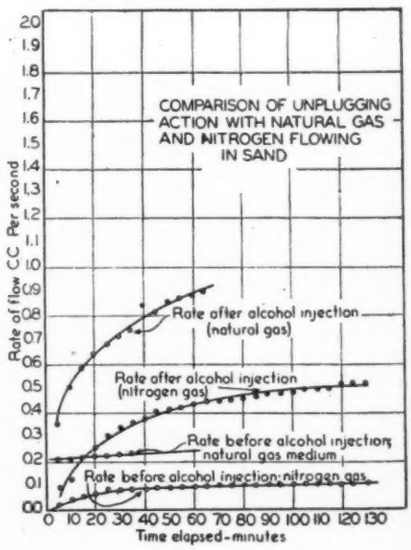
Editor's Note: This article will be concluded in an early issue of *The Petroleum Engineer*.

☆ ☆ ☆

Fig. 11. Comparison of unplugging action with natural gas and nitrogen flowing in sand


COMPARISON OF UNPLUGGING ACTION WITH NATURAL GAS AND NITROGEN FLOWING IN SAND
Rate after alcohol injection (natural gas)
Rate after alcohol injection (nitrogen gas)
Rate before alcohol injection; natural gas medium
Rate before alcohol injection; nitrogen gas
Rate of flow CC Per second
Time elapsed-minutes

Due to the impenetrability of the swamps it was sometimes necessary to make up the pipe on solid ground and shove it into place

Laying Pipe Line in Swamps Presents Difficulties

Petroleum Engineer Exclusive

☆ Gulf Coast areas of Louisiana and Texas tax ingenuity of pipeliners

by Frank H. Love

Managing Editor

Photographs by J. E. Hampson, Arkansas Natural Gas Corp.

PIPELINING in certain areas of the Louisiana and Texas Gulf Coast is attended by numerous difficulties because of the many swamps and bayous. Due to the fact that the area is almost inaccessible, special construction methods have to be adopted. Roads must be built of timbers through sections where the ground is virtually bottomless. At times stringing trucks with their loads of pipe find it impossible to reach the right-of-way under their own power and must be assisted by tractor. Line pipe must be welded into long sections and shoved into place where construction equipment cannot penetrate. These and many other special methods peculiar to the specific job must be employed, adding to the difficulty and the time

Problems were also encountered in laying pipe through rice fields

consumed in laying a pipe line through the area.

Construction of a 12¾-in. O. D. pipe line was recently completed in that section by the Arkansas Pipeline Corporation, Shreveport, Louisiana, acting as agents for the Empire Pipeline Company of Bartlesville, Oklahoma. The contractor was Anderson Brothers.

The line extends from Lake Charles, Louisiana, to Sour Lake, Texas. Because of varying conditions, pipe of 3 wall thicknesses was used. That laid in swamps had a wall thickness of 5/16 in., river pipe was ⅜ in., and the rest of the line pipe was ¼ in.

An accompanying illustration gives a graphic picture of the condition of the right-of-way. Trees were cut and stumps blasted before the pipe trench could be made. The pipe shown was shoved into place by tractors located on the nearest firm soil. With slings fastened around the pipe and the ends closed by a bull plug, two tractors gradually shoved the pipe into place as 3-joint sections were added. After it had floated into the proper position the bull plug was removed to allow the pipe to fill with water and sink to the bottom of the trench. The longest single "shove" of this kind was 9100 ft.

River Crossings

Two important rivers were crossed, the Sabine and Neches, as well as two major bayous that bore the rather commonplace names of Big Bayou and Little Bayou. Both rivers are 400 ft. wide from water edge to water edge. The Sabine is 30 ft. deep and the Neches 28 ft. As both are navigable streams it was necessary to bury the line a specified depth of approximately 2 ft. below river bottom.

In laying the Sabine River crossing it was impossible to find firm ground nearer than 3 miles to the point of crossing. Consequently, the full width of the crossing was made up complete including the 1200-lb. clamps, and floated down river supported by steel drums used as buoys and guided by a launch.

It was possible to make up the Neches River pipe on shore at the point of the crossing. After the joints were welded and the river clamps installed, the front end of the pipe string was attached to a barge and pushed across.

Big Bayou and Little Bayou also were laid 2 ft. below bottom, being classi-

Top—Because firm ground could not be found nearer, pipe for the Sabine River crossing, after being made up, was floated 3 miles downstream. Center—With a clamp holding the pipe ends in place an electric weld is being made. Bottom—It was not an uncommon thing for stringing trucks to be pulled into the right-of-way by tractors

fied as navigable streams. In both instances the pipe was made up and pushed in. At the bayous the pipe was cut, bends made on a barge, and the pipe rewelded into the line. Big Bayou is 25 ft. deep and more than 100 ft. wide.

Pipe Coating

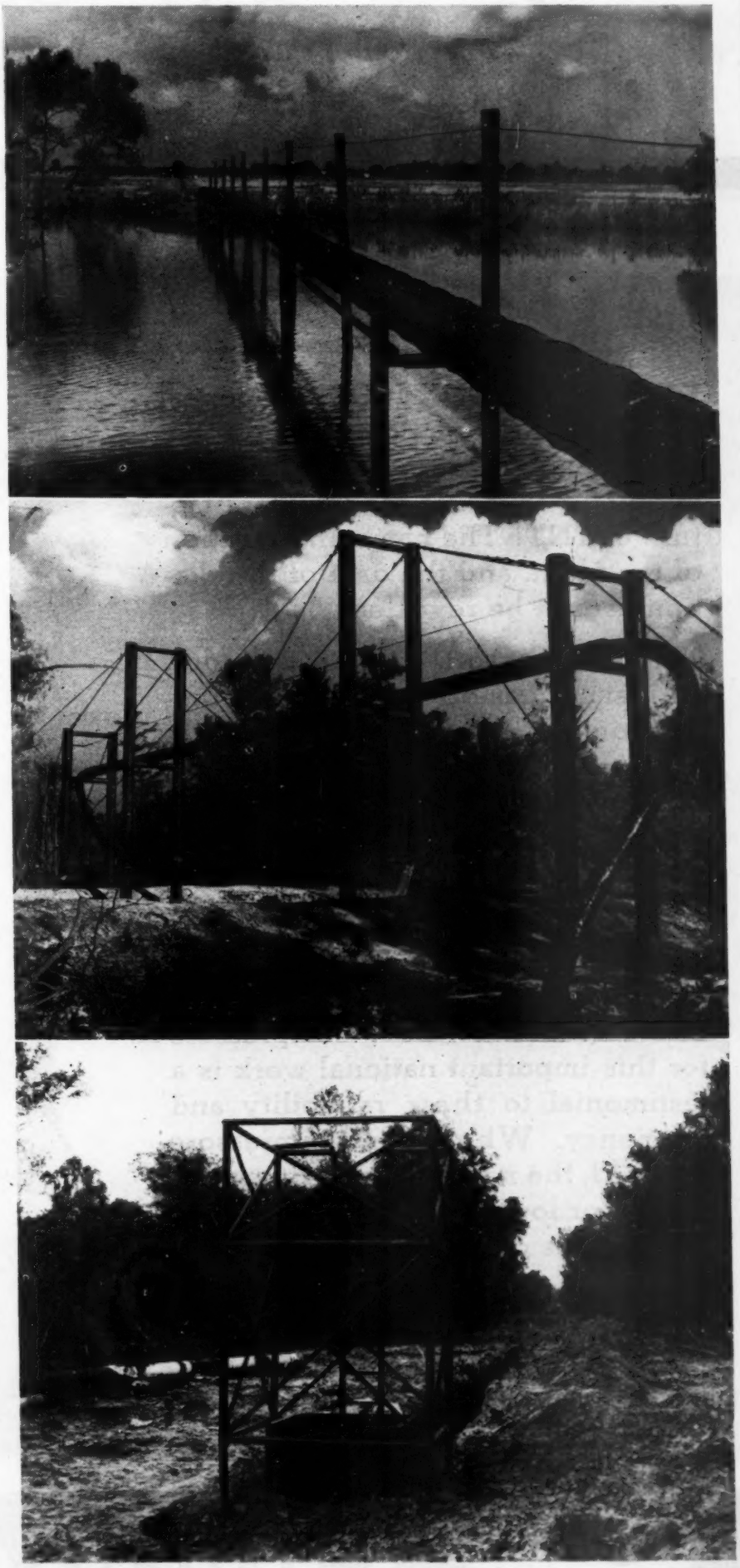
All pipe used in swampy areas and for river crossings was coated in central yards, three being established at locations convenient for this purpose. Hot enamel, asbestos felt, and kraft paper were applied to the pipe. For the rest of the line only enamel and asbestos felt were used, being applied by traveling-type combination coating and wrapping equipment after the pipe had first been cleaned and primed.

Rice fields, of which there is an abundance in the area, provided their share of difficulties. Across such areas the pipe was supported on bents made of 4-in. pipe, as shown in an accompanying illustration. The pipe was placed inside 16-in. casing. The space at the end of the casing was left unsealed, and as the casing ends extend beyond the levee oil will not run into the water and damage rice crops in event of a leak. Casing was coated and line pipe was placed inside by means of welding-on joints and pushing the pipe through one end of the casing.

On each side of both rivers and at high points on both sides of extensive swamps cutoff valves have been placed. The valves are set in a concrete box above which is an elevated tower or platform. By use of a long stem key flow of gas can be shut off from this platform during high water.

Crossing of the canal supplying the city of Beaumont with water presented a minor difficulty. Because city officials feared contamination of the water supply in event of a leak it was necessary to construct a suspension bridge rather than lay the line beneath the canal. Although the canal is but 50 ft. wide the entire bridge is approximately 100 ft. long. The four supports, set in concrete, were made of secondhand 16-in. pipe. Crossarms are of 8-in. pipe and the braces at the top of the supports are of 6-in. pipe. The cable used is 3-in.

The line is to be cathodically protected over its entire length with 54-amp. rectifiers. These have not yet been installed, however. —— ☆ ☆ ☆



Top—Through flooded rice fields the pipe was supported on bents made of 4-in. secondhand pipe. Center—A suspension bridge was constructed over the canal supplying water to the city of Beaumont, to prevent possible contamination should a leak occur. Bottom—At points where high waters frequently occur an elevated tower was placed over gate valves. Shutoff is by means of a long stem key

24 G-MV's (ANGLE) DELIVERING Producing

TWENTY-FOUR 1000hp Cooper-Bessemer G-MV compressors in a new western arsenal, turning out synthetic ammonia for the manufacture of TNT! The name and location of the plant, and the date of installation cannot be revealed.

The compressors are ten-cylinder, multistage gas-driven V-angle compressors of the compact type widely used in the manufacture of synthetic rubber, plastics, chemicals and other war and peacetime products. Either gas or diesel fuel can be used and the switch from one fuel to the other can be accomplished by making only a few simple changes.

The selection of these compressors for this important national work is a testimonial to their reliability and efficiency. Wherever compressors are used, the name Cooper-Bessemer stands for low over-all cost and long trouble free operation.

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World's Deepest Well Drilled in West Texas

☆ Phillips Petroleum Company well Ada Price No. 1, Pecos County, drilling past 15,255 ft.

by C. C. Pryor
Associate Editor

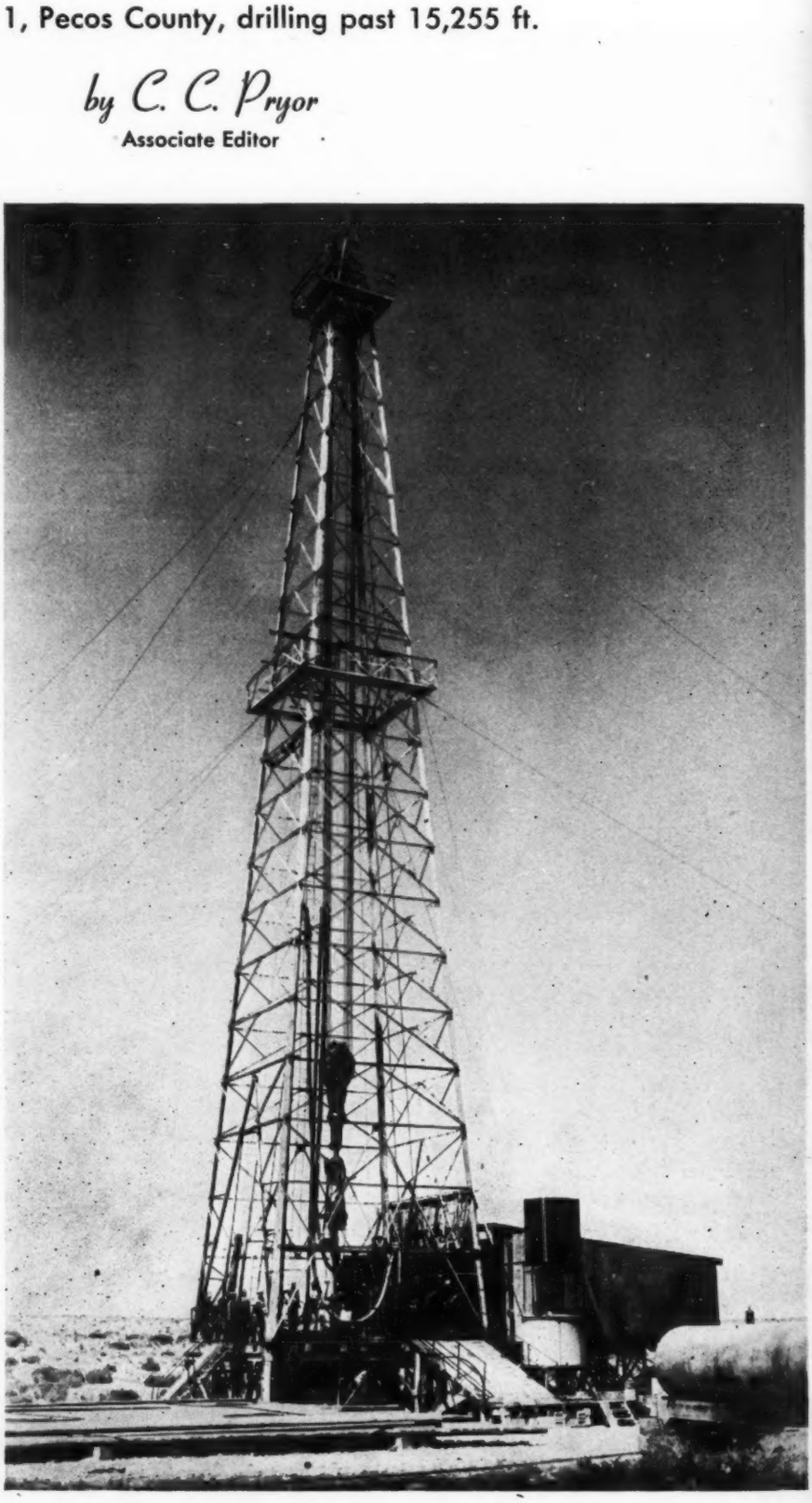
THE world's deepest well record was passed March 28, 1944, and a new record is being established in Pecos County, Texas, by the Phillips Petroleum Company Rig No. 20 with the Ada Price No. 1. The well was drilling at 15,255 ft. on April 12 when a new core was taken. This is 251 ft. beyond the previous record-depth well of 15,004 ft.

The deep wildcat was spudded June 30, 1942, 1980 ft. from the north and west lines, section 11, block 101, T. C. Ry. survey. The well is 35 miles south-southeast of the Apco pool and 30 miles southeast of Fort Stockton and Yates. Decision to drill on the block resulted from a combination of gravity and core drill work, the area later being surveyed by seismograph. No particular depth of the well has been announced either before or since the record depth has been passed. The objective of the operators is a thorough test of the oil and gas bearing possibilities of the structure.

Hard Formations

The elevation of Ada Price No. 1 is 3257 ft. Comanchean limestone was drilled from the surface to 510 ft. with a standard cable tool rig. From this depth to 1810 ft. the rotary drill penetrated top lime (dolomite). Lime, sandy lime, and dolomite were drilled to 5250 ft., at which point the first shale was found. Shale, lime, sand, and dolomite were drilled to 11,469 ft.

At this depth chert was encountered, causing extremely difficult drilling and coring. Drilling bits from 11,469 ft. to 11,471 ft. each drilled 1 ft. From 11.471 ft. to 11,472 ft. two bits were used, one drilling 9 in. and the second bit 3 in. Drilling from 11,472 ft. to 11,481 ft. required 3 bits and reaming the hole from 11,472 ft. to 11,494 ft. wore out 2 bits. Coring was necessary through the various strata drilled, but all such operations were extremely diffi-



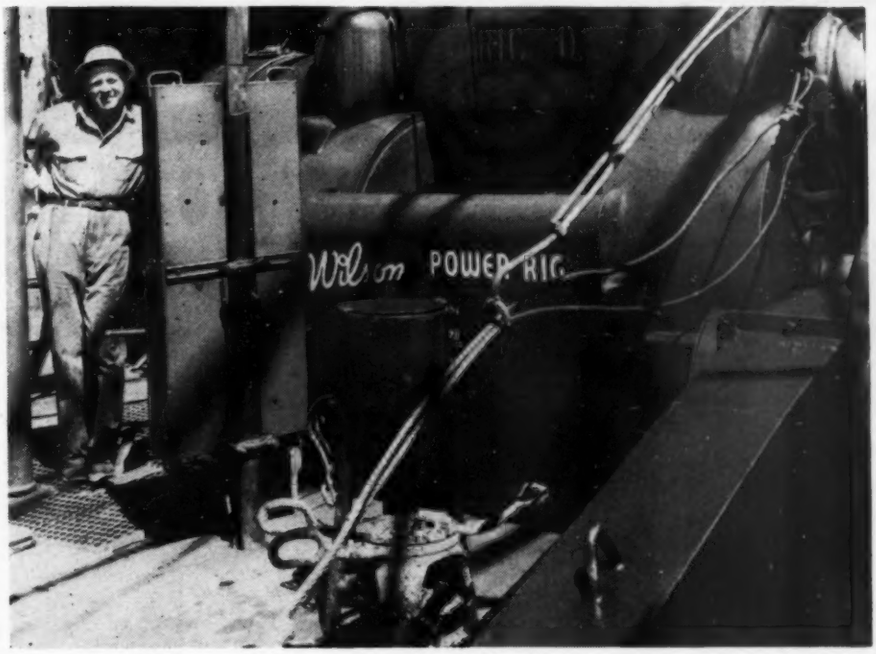
Ada Price No. 1, Pecos County, Texas

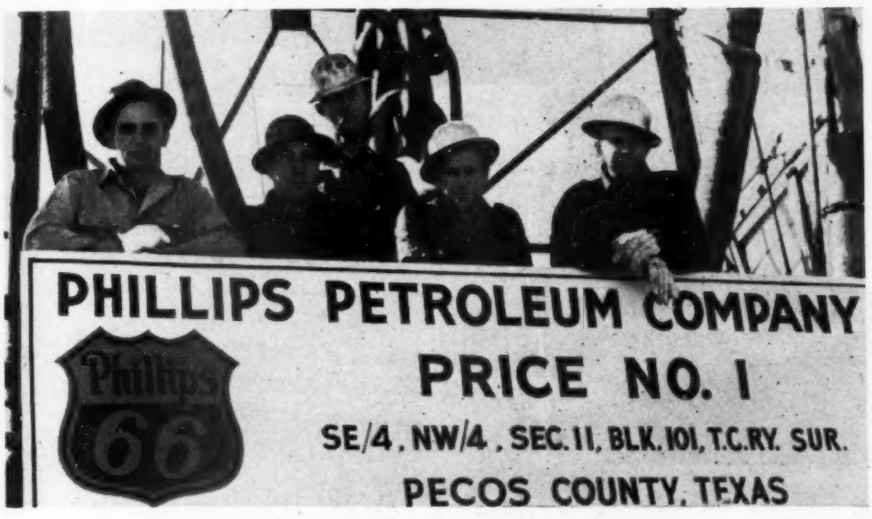
cult. At a depth of 11,556 ft. the operator ran core barrel for 1½ hr. without making hole—the core head was badly worn.

Extremely hard formations drilled in the well from 6901 ft. to 12,953 ft., which totaled 6052 ft., required use of 370 bits. The depth drilled per bit ranged from 0 in extremely hard formation to as much as 62 ft. in the softer zones for an average depth per bit of about 16 ft.

The most difficult section of the well to drill was from 12,830 ft. to 12,953 ft. through the chert. This section required 100 bits and the operator was able to core only 6 in. in one portion of the section that was soft enough. Approximately 4 months were required to drill the 123-ft. section, including shutdown time for various reasons.

The formation below 12,953 ft. gradually became softer as lime sections were encountered. The Simpson lime was topped at 13,100 ft. and at 15,070 ft. drilling was still in the lime streaked with shale. A total of 32 bits was used in drilling from 12,954 to 15,017 ft., a distance of 2063 ft., and an average per bit of about 64 ft. More than 500 bits have been used in drilling the well; and 15 reamers were used to condition the hole to 6940 ft. for casing.





Above—Z. E. Aldridge, driller, who was on tour when the depth record was broken, and the 12,000-ft. drawworks that was put in operation from 13,029 ft.

Left—Left to right: A. G. Baker, driller; E. L. Powell, pumper; R. W. Holder, engine man; R. A. Davenport, derrick man, and Vim Jeffreys, mud man

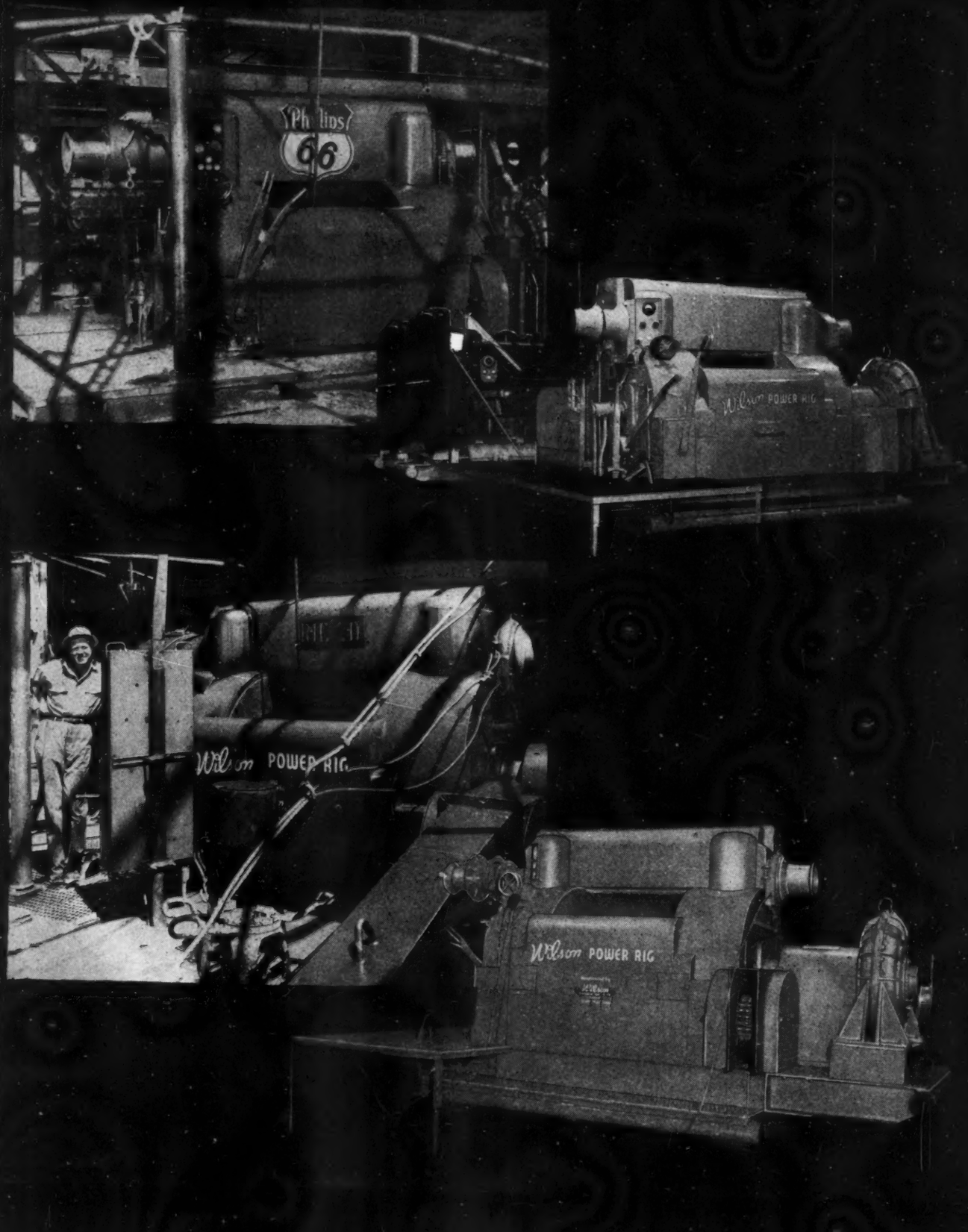
Below—G. N. Whitman, rig superintendent and day tour crew members: Z. E. Aldridge, driller; J. W. Morgan, motor man; L. H. Long, roughneck; J. T. Burge, derrick man; R. L. Tucker, roughneck, and Charles Powe, roughneck

Casing

Casing of the hole began with cementing 20-in. pipe at 507 ft. with 970 sacks of cement. An additional 300 sacks of cement were run outside the 20-in. casing. Casing, 13⅜ in., was run and cemented at 1940.5 ft. with 1600 sacks of cement were run outside the 10,008 ft. was reached, 8⅝-in. casing was run and cemented at 6901 ft. with 200 sacks of cement.

No casing has yet been run below 6901 ft. as the strata penetrated by the bit is extremely hard and does not cave; also, should the well be plugged back for completion, casing below the plug-

THE POWER RIG
THE WORLD'S



G THAT DRILLED S DEEPEST WELL!

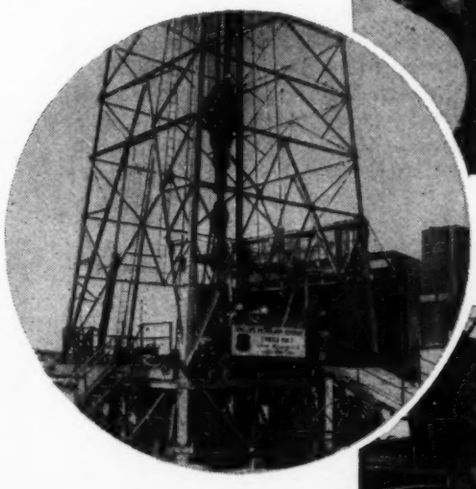
...and is still going!

Wilson Power Rigs have again proved they are all we claim them to be—and more!

On March 27th, a new world's record was set for depth—15,027 feet—with a *Wilson Power Rig*. And the hole is going deeper and deeper as this advertisement goes to press.

The well, Phillips Petroleum Company's No. 1, Mrs. Ada Price, Pecos County, Texas, was drilled to 13,029 feet with a Wilson Atlas Model Rig, rated for 9,000-foot drilling. At 13,029 feet, a Wilson Titan Model Rig, rated for 12,000-foot drilling, was installed. This rig carried the well to the greatest depth ever drilled; and is still drilling!

Left to right: Russell Moore, West Texas representati for Wilson Mfg. Co.; J. H. Wilson, president of Wilso Mfg. Co.; Glenn Whitman, rig superintendent for Phill Petroleum Co.; George Franks, West Texas serviceman Wilson Mfg. Co.; Z. E. Aldridge, driller on tour that broke the previous world's record.



Z. E. Aldridge, driller on the tour that passed the previous depth record, voiced the sentiments of the entire crew when he stated, "I was proud to work on such a fine rig!" He reported no mechanical trouble, and stated the rig was able to lift the 15,000 feet of drill pipe in third speed with ease (two lower speeds unused). In low speed the rig could lift the entire load with one of the three Cummins 225 H.P. Diesel Engines. At 15,000-foot depth, only about four hours were required to come out of the hole, one hour to change bits, etc., and about three hours to go in the hole. Performance in every way was very satisfactory.

Many new improvements have been added to Wilson Power Rigs since these record-breaking models were manufactured, including the new Model Super Titan Rig designed for constant drilling at 15,000 feet. So, regardless of the depth well to be drilled, there's a Wilson Rig to do the job, and with record performance!

Left to right: Glenn Whitman, rig superintendent; Z. E. Aldridge, driller; J. W. Morgan, motor man; L. H. Long, floor man; J. T. Burge, derrick man; B. L. Tucker, floor man; Charlie Powe.

Wilson

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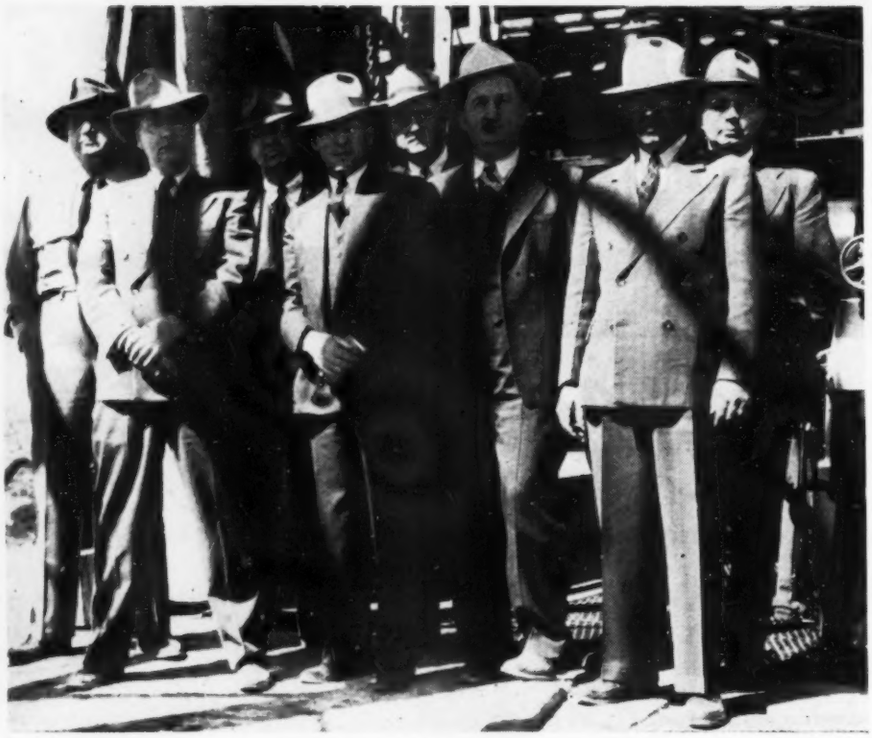


Phillips officials who visited the well included: l. to r., Glen Whitman, rig superintendent; M. L. Atkinson, assistant division superintendent; C. P. Dimit, vice-president in charge of production; Charles Daniels, division superintendent of western division; W. C. Russell, district superintendent; D. Ballew, superintendent of drilling division; Shirley Miller, district drilling superintendent, and J. S. Montgomery, regional superintendent

back depth will not be lost due to the difficulty of pulling casing at such depths.

Engine and Drawworks

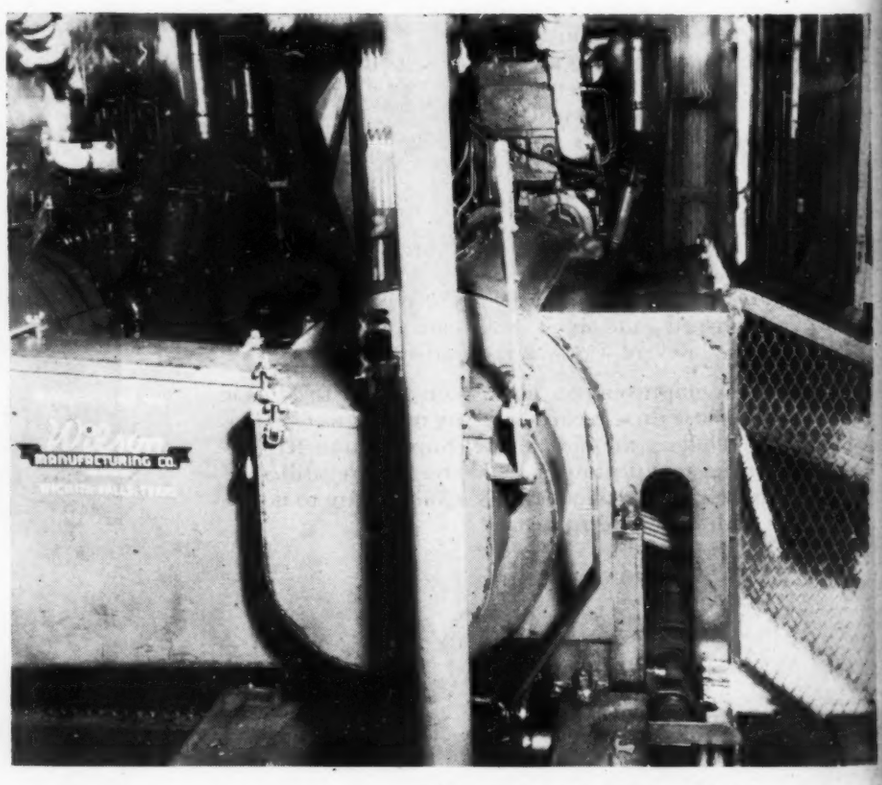
Drilling of the well was begun with a standard cable tool rig to penetrate the hard Comanchean limestone. Twenty-five days were required for the rig to drill 520 ft. The cable tool rig was then torn down and a rotary rig assembled and placed in operation. Rigging time for the rotary rig and drawworks was seven days. This rotary rig was designed for use with 4½-in. drill pipe to drill to depths of 9000 ft. The well was drilled to 4953 ft. with 5-in. drill pipe; 4-in. drill pipe was then used to drill the well to 10,008 ft. A string of 3½-in., grade D, drill pipe was run into the hole for further drilling. The first rig was used to drill the well to 13,029 ft. At this depth it was considered advisable to employ a heavier drawworks, and one designed for 12,000 ft. was placed in operation.

The first drawworks was equipped with 12-cylinder, v-type engines, using butane as fuel; whereas the second unit was equipped with full diesels. Both units had seen much service previously on other wells. Rig and rotary table were also changed to heavier type equipment. Two of the three 7-in. by 10-in., 6-cylinder, diesel engines with piston displacement of 2309 cu. in. and 225 hp. on the drawworks were first placed in service in 1937. One has had 38,880 hr. and the other 39,768 hr. of operation. The third engine, in use since 1938, has 29,520 hr. of operation and the standby mud pump engine placed in operation in 1941 has 17,280 hr. According to the driller's log, dependable service has been obtained from the engines.

In use when the well passed the depth record, the drawworks was designed for heavy duty. It employs interchangeable friction clutches throughout, providing unusual flexibility. The three engines are chain compounded with the chains running in an oil bath. Transmission for the drawworks is an enclosed chain type with 6 speeds forward and low and high reverse. It has a 48-in. long, 24-in. O.D. drum of 1-in. seamless steel construction and is of the free rolling live-shaft type.

The brakes on the drawworks are an improved type with long equalizer, single nut adjustment and flame hardened, ground and polished surfaces. A new type friction latch on the brake lever permits locking the lever at any point to provide a constant rate of feed for the drill pipe, thus maintaining a uniform weight on the bit. The low-speed drum clutch is an internal expanding shoe type friction clutch as is also the high speed drum clutch. As the brake rings are water cooled and the high speed clutch is mounted inside the lefthand brake ring, both clutches are water cooled. All chains outside the transmission are adjustable and run in oil bath except final drive chains to drum, cathead shaft, and rotary table. The engines are compounded to permit

(Continued on Page 80)



Rear engines and mud pump drive clutch

Cummins Diesels Break Another World's Record

When the going got tough at 13,059 feet on Phillips No. 1 Price, Pecos County, 3 Cummins Diesels of 225 HP (compounded) were moved on to do the job. These engines, 6 and 7 years old, had already drilled 108,168 total hours . . . are now drilling below 15,160 feet *and going strong*. Another 225 HP Cummins Dependable Diesel powers the stand-by pump. Regan Blocks, also exclusive with Mid-Continent, and a Wilson Titan Rig, distributed by Mid-Continent, were selected to stand the gaff in drilling this world's deepest well.

We Congratulate Phillips Petroleum Co.

We have available for delivery Wilson Rigs powered with Cummins Dependable Diesels and all other equipment for complete drilling rigs identical or equal to that used on this well. No long delays in getting this material when you come to Mid-Continent Supply Co.

Now Is the Time! Be Wise—Modernize—Dieselize—Standardize With Cummins.

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OIL & GAS WELL — PIPE LINE — GASOLINE PLANT — REFINERY SUPPLIES

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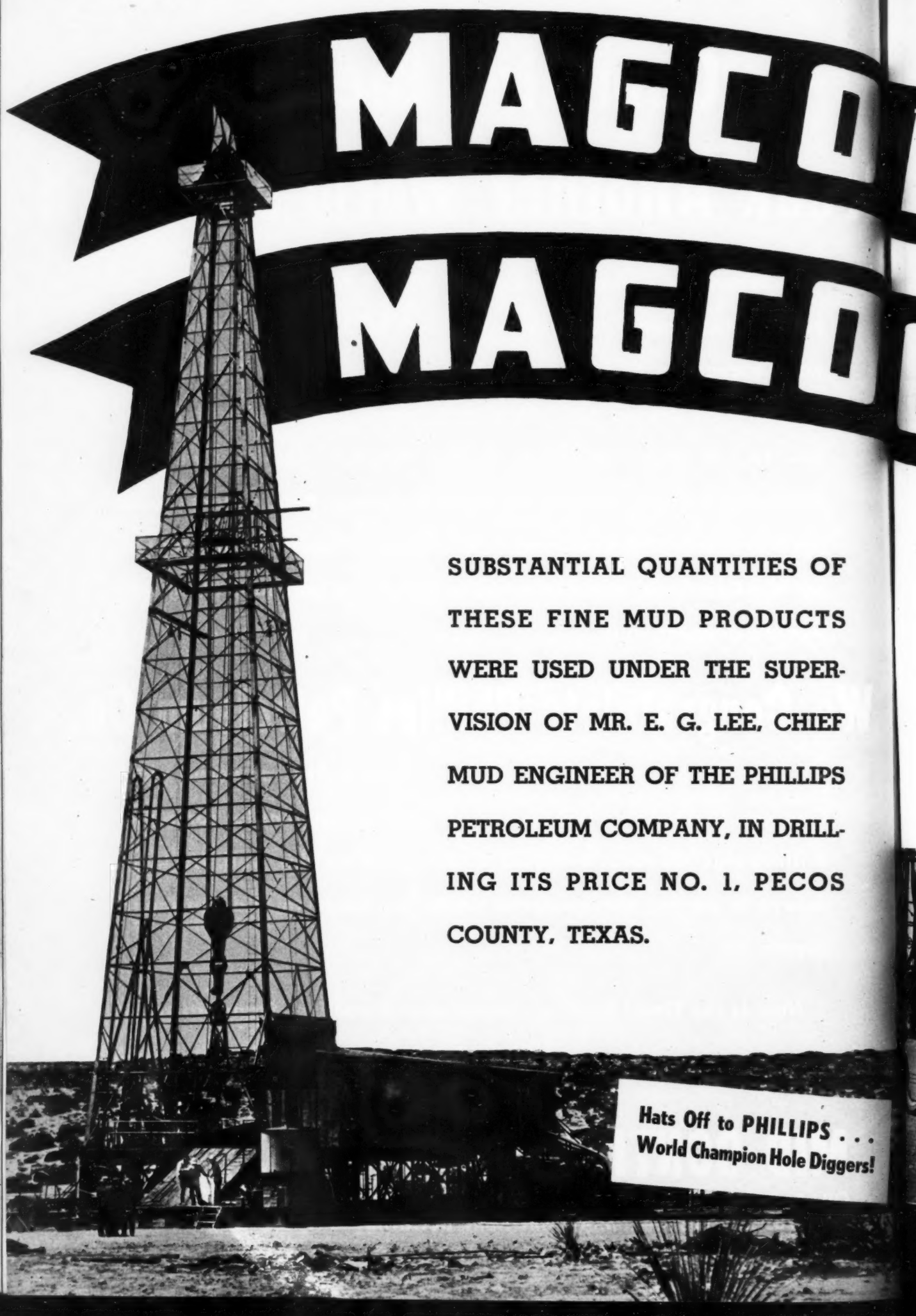

SUBSTANTIAL QUANTITIES OF THESE FINE MUD PRODUCTS WERE USED UNDER THE SUPERVISION OF MR. E. G. LEE, CHIEF MUD ENGINEER OF THE PHILLIPS PETROLEUM COMPANY, IN DRILLING ITS PRICE NO. 1, PECOS COUNTY, TEXAS.

Hats Off to PHILLIPS . . .
World Champion Hole Diggers!

BAR — HIGHEST MUD WEIGHT —LOWEST VISCOSITY!

CLAY — LOW WATER LOSS —HIGH-YIELD CLAY!

We are grateful to the oil industry for the fine reception it has given Magcobar Weighting Material. Nearly three million bags have been used by the oil well drilling industry since it was introduced to the trade in 1941. This unusual acceptance is due to:

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2. Price—We pioneered reasonable priced weighting material which has resulted in a saving of approximately 50% to the oil industry.
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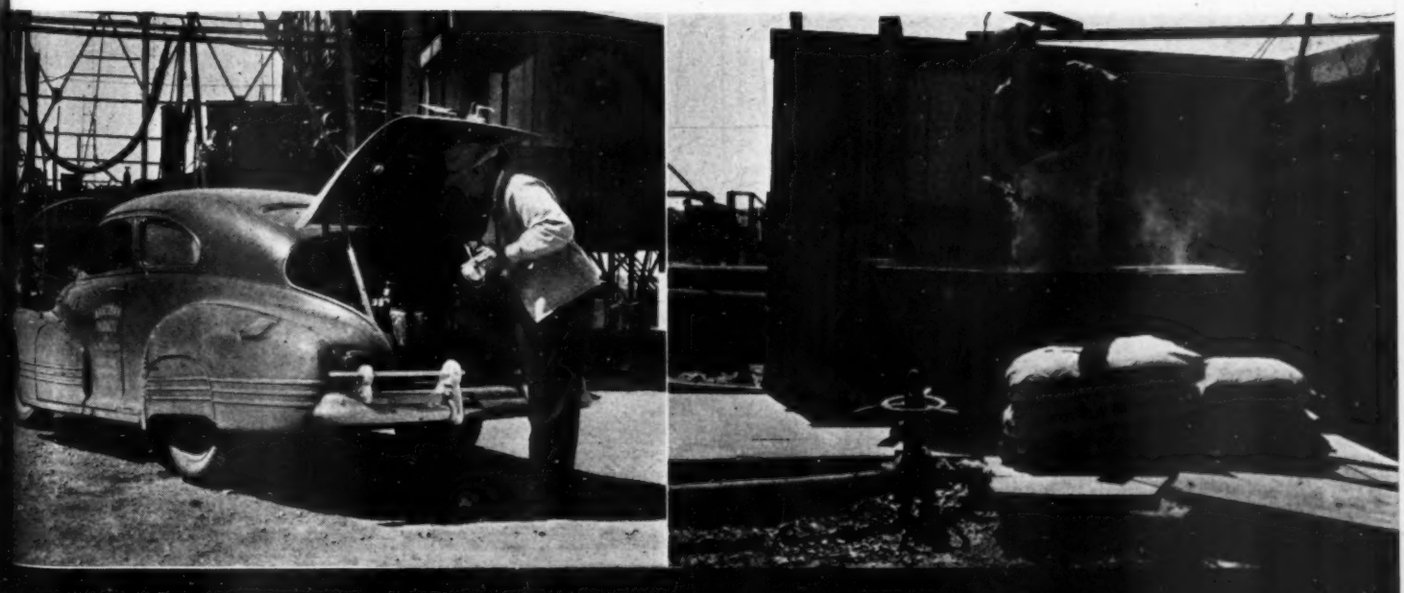

(Continued from Page 76)

ANALYSIS OF OPERATIONS TO 14,708 FT.
Ada Price No. 1—Rotary Rig No. 20

Section	Date start	Date comp.	Elapsed days	Oper. days	Drlg. days	Day time	Lay down drill pipe and run casing	Days s.d. repairs	Days fishing	WOC	Other s.d. time
Cable tool surface hole 0-520 ft., ran 20-in. csg.	6-28-42	7-28-42	30½	28							
Rotary Operations											
Rig up rotary	8- 5-42	8-11-42	7							7	
Drill 520-1948 ft. ream, run 13⅜ in. csg., and WOC	8-12-42	9- 1-42	21	17½	12½	..	1½	1	3½	2	½
Drill 1948-6901 ft. hole reduced	9- 2-42	11-14-42	73½	70¼	60¾	..	1	3¼	8	..	1½
Drill 6901-10,008 ft., run 8⅝-in. csg. to 6901 ft., WOC, and repairs	11-14-42	4-17-43	154½	111½	98	2	2½	29½	19	2	1½
Drill 10,008-12,829 ft. (to chert)	4-18-43	9-24-43	160	128	100	8½	....	31½	19½	..	½
Drill 12,829-12,954 ft. (chert)	9-25-43	1-25-44	122½	85	80	5	....	27½	0	..	10
Drill 12,954-13,029 ft. changed rigs	1-25-44	2- 7-44	13½	6	4	2	....	½	0	..	7
Drill 13,029-14,708 ft. (depth on 3-19-44)	2- 8-44	3-19-44	41	38½	33	5½	....	2½	0	..	0
Total to date	8- 5-42	3-19-44	593	456¾	388¼	23	4	95¾	50	4	28
Per cent time on location.			100%	77	65.5	3.9	0.9	16.1	8.4	0.9	4.7

Left—top to bottom, C. P. Dimit, vice-president of production; A. G. Baker, driller; R. W. Holder, engine man; E. L. Powell, pumper; R. A. Davenport, derrick man, and Vim Jeffreys, mud man.

Right—Sectional map of main producing areas of West Texas and location of the deep well, Ada Price No. 1. Below—view showing layout of rig No. 20

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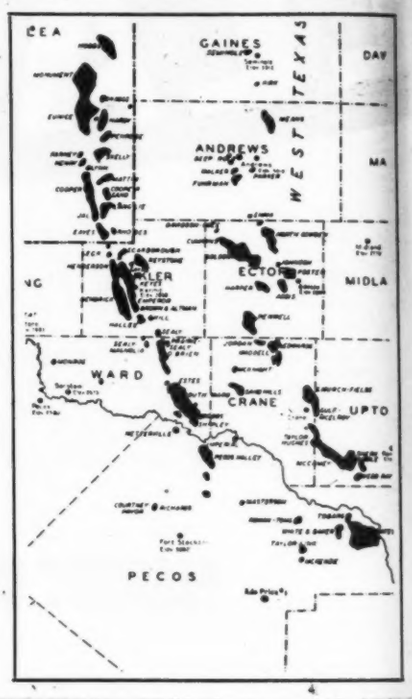

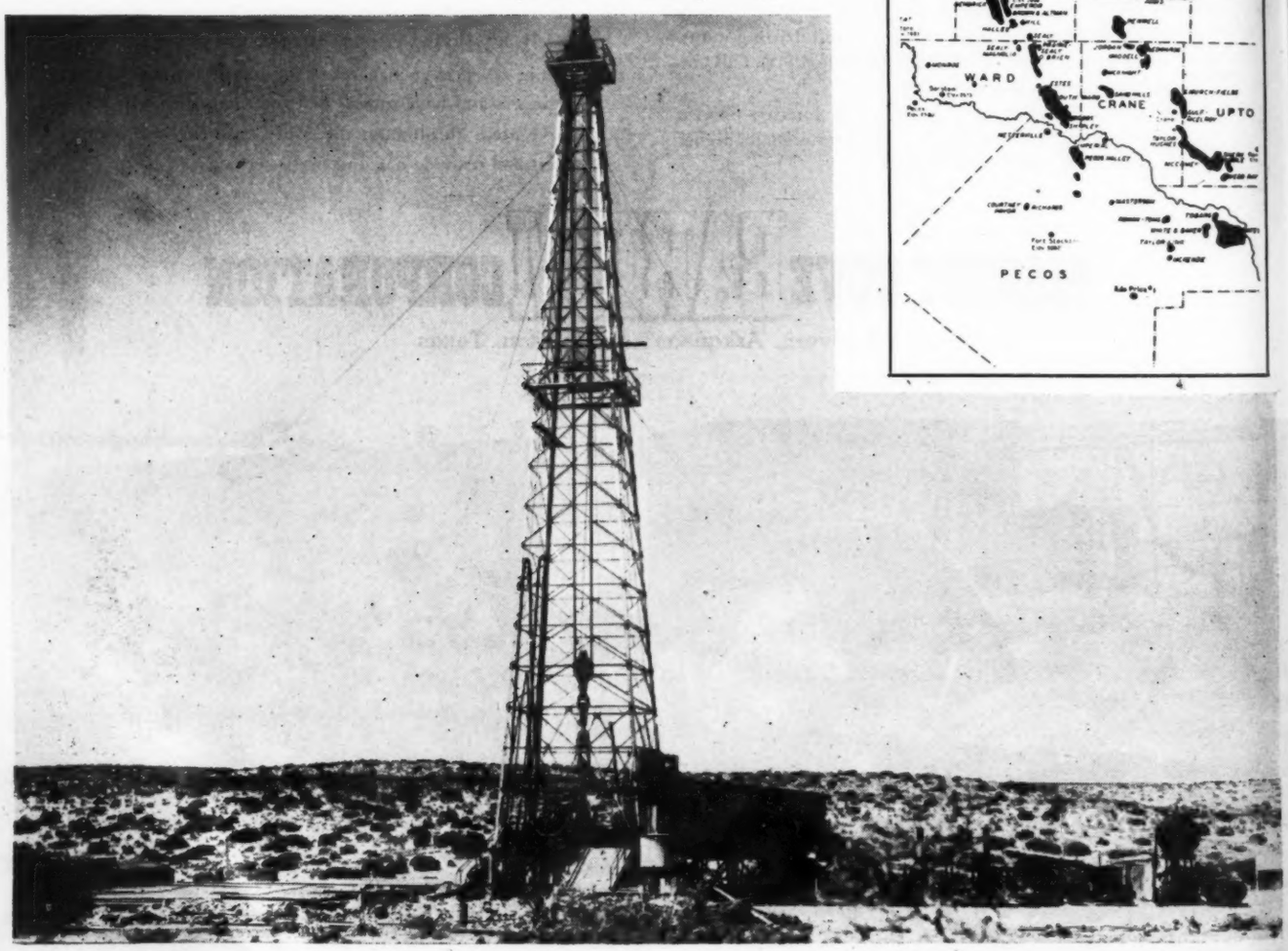

GARDNER-DENVER 8 x 20 FXL POWER SLUSH PUMPS *ARE HELPING TO SET NEW RECORDS ON THE WORLD'S DEEPEST WELL...*

• Phillips Petroleum Company's Price No. 1, Pecos County, Texas

Today, Phillips Petroleum writes a new chapter in the history of man's unremitting search for oil! Price No. 1—world's deepest well at 15,017 feet, and still going strong—stands as a tribute to modern engineering resourcefulness and skill.

Gardner-Denver, in congratulating the new record holder, is proud that Gardner-Denver 8 x 20 FXL Power Slush Pumps are being used all the way . . . additional evidence of their ability to deliver top-notch performance under toughest of modern deep-well operating conditions.

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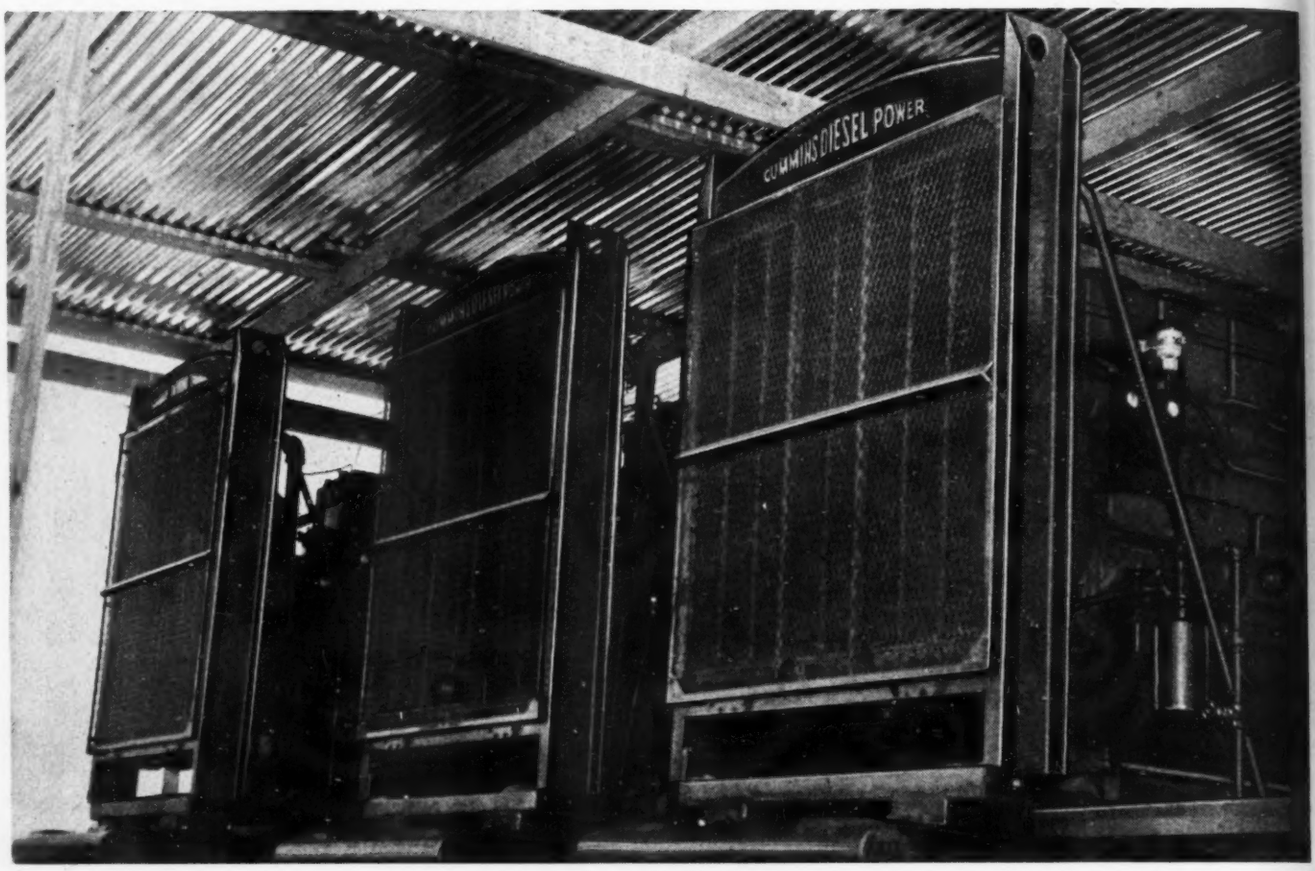
Republic Supply Company (of California), 2122 E. 7th Street, Los Angeles, California; Continental Supply Co., Continental Building, Dallas, Texas.

GARDNER-DENVER Since 1859

WORLD'S RECORD FALLS!



In West Texas, 27 miles southeast of Fort Stockton, the Phillips Petroleum Company's Ada M. Price No. 1 has been drilled to a level of 15,025 feet (as of March 30) to set a new world's record for deep well drilling. The Wilson Titan rig on the job is powered with the three 225 hp. Cummins Diesels shown here, all being compounded to operate the drawworks. A fourth 225 hp. Cummins Diesel provides auxiliary power for the mud pump.

Cummins-Powered Wilson Titan Sets New Drilling Mark

West Texas, March 30—The eyes of the petroleum industry are today focused on Pecos county, Texas, where, at the Phillips Petroleum Company's Ada M. Price No. 1, drilling has reached the depth of 15,025 feet—as of this date—to establish a new world's record for deep well drilling.

Particular importance is attached to this operation because this new record has been established by a rig using internal combustion engines. The rig in question is a Wilson Titan, which uses three 225 hp. Cummins Diesel engines, all compounded, to operate the drawworks. A fourth Cummins Diesel of the same horsepower capacity is used as an auxiliary on the mud pump.

The Cummins-powered Titan rig was moved in on the 13,029 feet, replacing a Wil las rotary rig which, at t treme depth, was found t light for further use.

Spudded in with cable June 31, 1942, the well ha writing reached a depth feet, ex by 21 fee vio w t ca co it is believed that the rig is capable of going beyond the 16,000 foot level.

Situated 27 miles southeast of Fort Stockton, Texas, the record-shattering Phillips operation is supervised by D. L. Ballew, general drilling superintendent for Glenn Whitman, tool pusher on the rig.

To Phillips—we say "Congratulations!"

. . . and to drilling operators we say, "For cheaper, faster footage, and dependable power performance every foot of the way—power your rig with Cummins Dependable Diesels." CUMMINS ENGINE COMPANY, INC., Columbus, Indiana.

CUMMINS Dependable DIESELS

SINCE 1918—PIONEER OF PROFITABLE POWER THROUGH HIGH SPEED DIESELS

WORLD'S DEEPEST HOLE

uses the

Industry's Most Dependable

MUD SCREEN

Phillips' Ada Price No. 1 wildcat using a Link-Belt Type NRM-124 Dual Mud Screen.

Phillips Petroleum Company's Ada Price No. 1 wildcat, near Ft. Stockton, Texas, has broken all previous depth records, drilling ahead April 7th at 15,195 feet.

It takes capable men and dependable equipment to accomplish such a record, and Link-Belt NRM-124 Dual Mud Screen was used to recondition the drilling mud for this valuable operation.

It is not unusual that a Link-Belt Mud Screen had a part in helping to drill this new record depth. A Link-Belt Screen was used on the previous world's record depth hole, 15,004 feet in California . . . on the world's deepest producing well, 13,266 feet in DeLarge Field, Louisiana . . . on Texas' deepest hole, 14,378 feet in Old Ocean Field . . . as well as on most other record depth holes.

Send for Folder 1872-A for full details of this Mud Screen.

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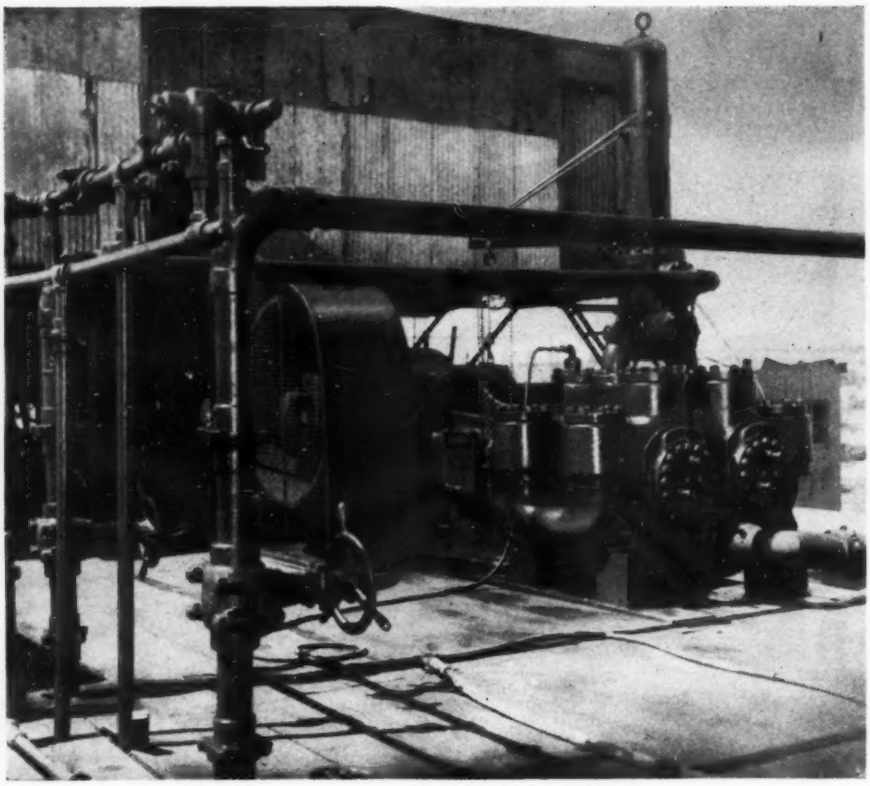

Main mud pump, 8 in. by 20 in., driven by 18 v-belts from the rear engine on the drawworks. Six-in. liners were used in the divided fluid end type pump

(Continued from Page 80)

use of two for the drawworks and one for the mud pump. Each engine is equipped with a friction clutch so that it may be taken out of service when not required. A separate clutch provides for the mud pump to be shut down if necessary.

Mud Pumps

Power for the main mud pump is delivered by the third diesel on the drawworks by 18 v-belts. This pump is on the ground level behind the drawworks and engine structure. The size of the main pump is 8 in. by 20 in., 425 b-hp., and is divided-cylinder valve-pot type of construction. It has an average displacement of about 700 g.p.m. and operates at about 1500 lb. The gear ratio is 5:1. The suction pipe is 10 in. and the discharge 4-in., which is equipped with a 2-in. relief valve.

The pump was fitted with 6-in. liners as the well depth increased. An auxiliary or standby pump of the same type, 7¾ in. by 16 in., was also diesel-engine driven with v-belt power transmission. It has a gear ratio of 4.77:1, b-hp. of 250, and intake pipe size of 8-in. and 4-in. discharge.

Average mud weight used in the well was 12.1 lb. having a viscosity of about 50. The well was drilled to 12,839 with 11.3 lb. mud and changed to 12.1. Further mud conditioning was made at 12,851 ft., 12,947 ft. and 14,088 ft. Vibrating screen type shale shakers were used. Drilling mud was slightly gas-cut at several depths during drilling. Information on the depths of possible production, however, has not yet been released. Electric logs were run at total depths of 10,008 ft. and 15,007 ft. A geophone survey was run at 15,020 ft. and a temperature survey at the same depth with two thermometers recorded 235° and 240°.

In view of the hard formations drilled in the well very little difficulty was experienced with deviation of the hole. The greatest deviation occurred at 3130 ft. and was 1¾°. The average deviation of the hole was about ¼°.

To prevent possible shutdown and accidents from worn and fatigued drilling line, 10 changes were made to 15,040 ft. Ten-line blocks were used due to the large number of round trips to change bits and the excessive weight imposed on the line during drilling and round trips. Difficulty was experienced by the operator with more than a dozen fishing jobs for drill pipe and drill collars. The hard formations penetrated resulted in the hole being tight and caused the bits and pipe to bind and twist off the drill pipe. Stretch of the drill pipe in the deep hole was another factor responsible for several partings of the pipe.

Acknowledgment

Material and photographs for this article were supplied by Phillips Petroleum Company, Wilson Manufacturing Company, Cummins Engine Company, Gardner-Denver Company, Hughes Tool Company, and Magnet Cove Barium Corporation.

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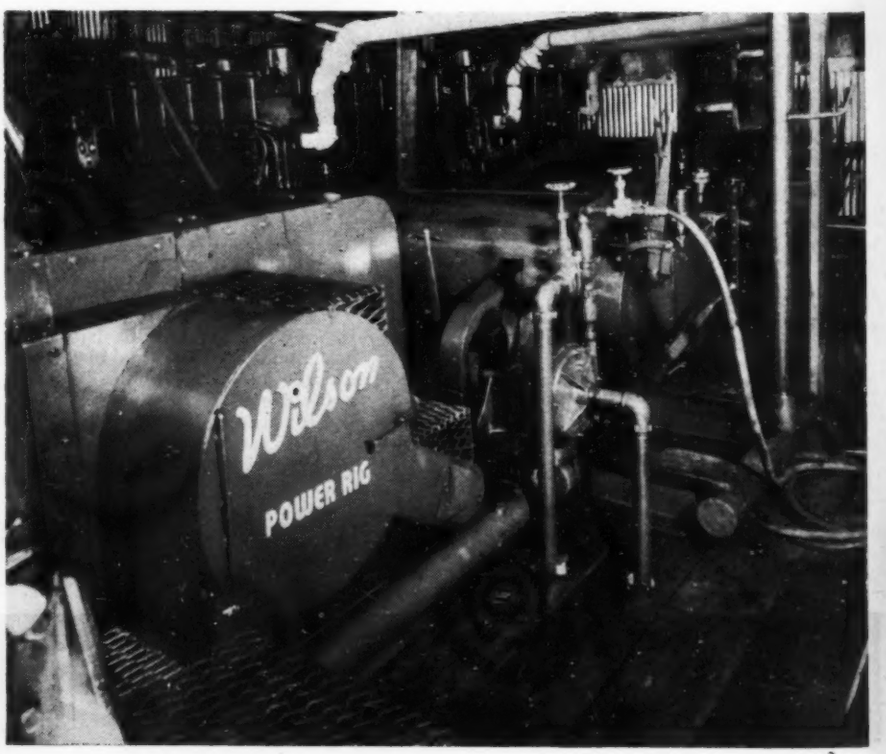
Below—Three 6-cylinder, 225-hp. diesels powered the drawworks and mud pump. Engine and drawworks clutches and transmission are also shown



Day and Afternoon Drilling Crews

World's Deepest Well

From Left to Right

First Row

Glen Whitman, Tool Pusher
Ben Gilliam, Tool Pusher
Chet Buzzard, Union Wire Rope Corp. Representative

Second Row

J. A. Leatherwood, Driller
Deb Herring, Roughneck
L. B. Whatley, Roughneck
G. F. Jones, Roughneck
Buck Thompson, Roughneck

Third Row

Z. E. Aldridge, Driller
C. L. Anderson, Roughneck (holding mascot-weevil hawk)
J. T. Burge, Roughneck
L. H. Long, Roughneck
Roy Lanier, Roughneck

F-44

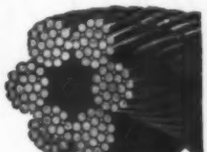
Here's To Phillips . . .
May Your WORLD'S DEEPEST Drill In The WORLD'S BIGGEST

Drilling on beyond the old world's record, at a depth within a few hundred feet of the 3 mile mark is indeed a feat deserving of a 24 gun salute.

Especially is this true in this war emergency—when petroleum is so vital that on the battle fronts around the globe it accounts for 60% (by weight) of battle supplies—when on the home front, despite restrictions, it has come to account for one-eighth of all freight tonnage.

More and more oil must be discovered. For going to such great depth and for placing its resources fully behind the replenishment of our oil reserves, the Phillips Petroleum Company is owed a debt of gratitude by all America, by most of the world.

union-formed Wire Rope



On the Job Day and Night Since August, 1942

The entire Union Wire Rope organization is deeply proud of having a part in the drilling of the world's deepest oil well. For more than a year and a half Union-formed (preformed) Wire Rope has been in continuous operation on the Phillips rotary rig. The weight of equipment it handles has grown to 112 tons. At present depth a round trip of the rotary rope requires eight hours. The ton mileage it has run up is indeed impressive.

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union Wire Rope

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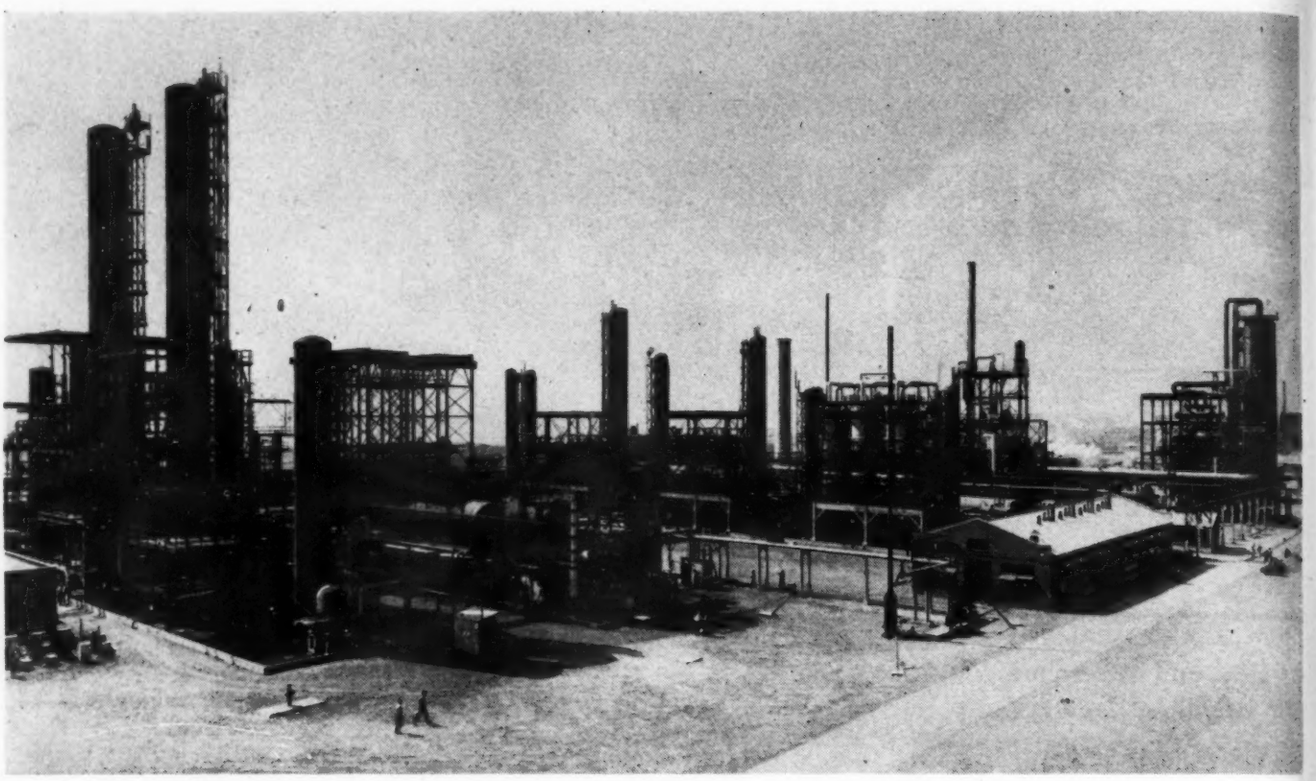


Bird's-eye view of Sun Oil Company's new aviation gasoline plant at Marcus Hook, known as 15 Plant

Sun's New 15 Plant Completes 100-Octane Conversion Program

PETROLEUM ENGINEER Exclusive Feature

☆ **Latest Houdry unit and HF alkylation plant increase aviation gasoline output**

by John H. Kunkel

Refinery Editor

BUILT at a cost of approximately $13,000,000, Sun Oil Company's new No. 15 Plant climaxes and completes a program undertaken by Sun in 1939 to convert its Marcus Hook, Pennsylvania, refinery for all-out production of 100-octane aviation gasoline. The conversion program, financed in its entirety by Sun Oil Company, involved a total expenditure of about $20,000,000.

No. 15 Plant, dedicated in October, is a self-contained unit for the manufacture of fighting grade, 100-octane aviation gasoline and further functions to link together the several Sun units at Marcus Hook devoted to production of 100-octane gasoline base stock. It consists, therefore, of a specially designed Houdry catalytic cracking plant, a Universal Oil Products Company hydrogen fluoride (HF) alkylation unit, which is one of the largest in the world, and a gigantic gas fractionation and stabilization plant.

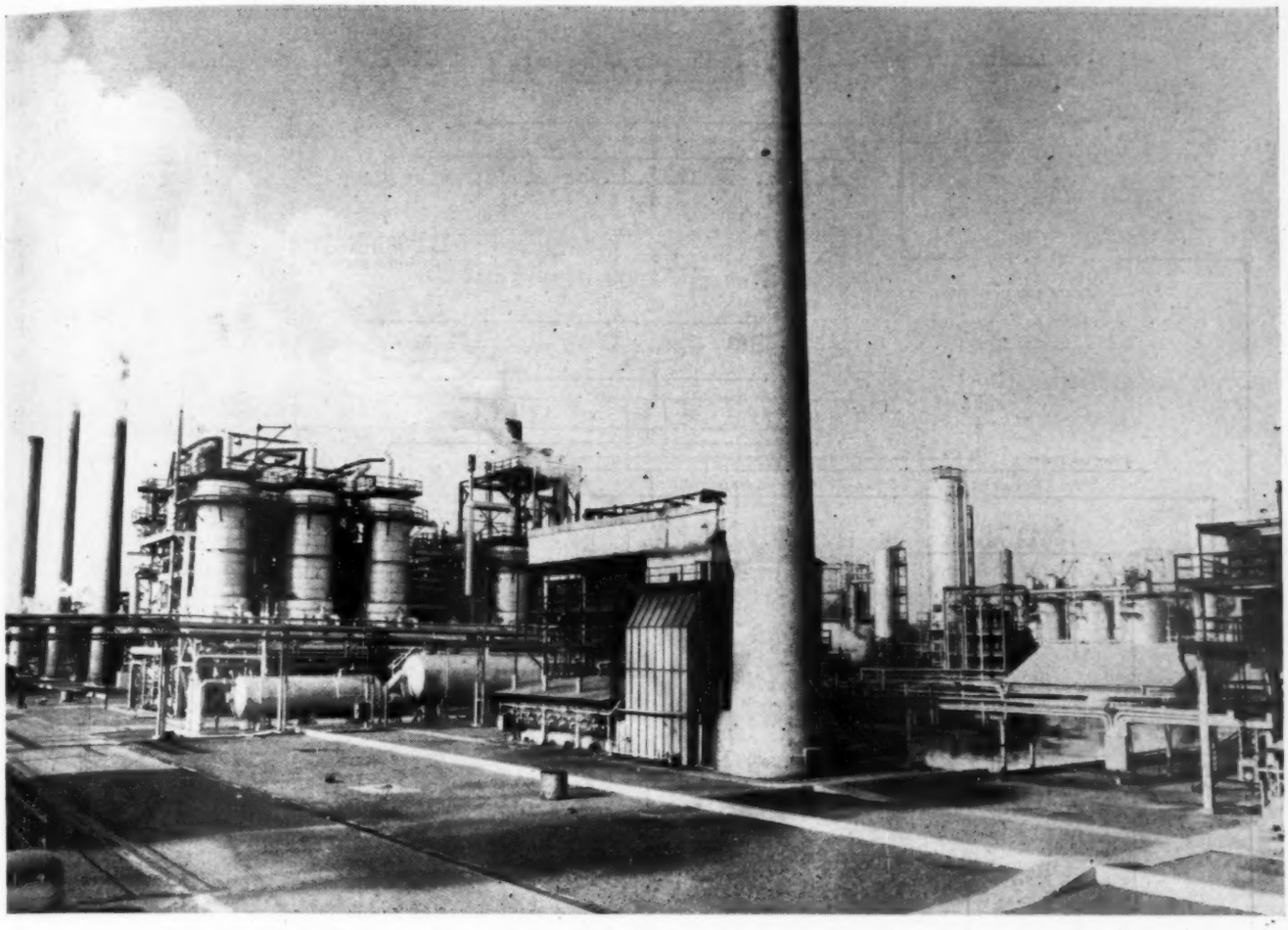
No. 15 Plant includes, as well, such supporting units as a 450-500 lb. per sq. in. boiler plant with a capacity of 225,000 lb. per hr. of steam at normal load, a water purification system treating 50,000,000 gal. per day of Delaware River water, an electric power substation, a chemical laboratory, warehouse, other essential buildings, and product storage facilities.

Background and Development

Although 15 Plant is but a part of Sun's huge Marcus Hook refinery, its importance to the whole is emphasized by the fact that it increases the company's production of 100-octane aviation gasoline to 12 times its prewar figure. Its capacity is a military secret but it can be said that sufficient 100-octane aviation gasoline is made here to fly 2000 four-engined bombers over Berlin and back each week.

The story of 15 Plant is inseparable from that of Marcus Hook. To understand 15 Plant's function and relation to the whole, it is necessary to understand something of the background of the Marcus Hook development.

Marcus Hook is Sun's principal refinery. It is located on the Delaware River, approximately 20 miles south of Philadelphia and 10 miles north of Wilmington. Its history began in 1901 when Sun purchased 62 acres of tidewater land for the erection of the original refinery placed there to receive marine shipments of crude oil from the Spindletop field in Texas, process it, and ship the finished products by water—later by pipe line as well—to domestic



Houdry catalytic cracking unit at Marcus Hook refinery. This unit is in 10-3 Plant and is one of the finest types of catalytic cracker, consisting of 12 cases

and international markets. The original refinery consisted of eight 700 bbl. batch stills, which in 1903 had a throughput of 1500 bbl. of crude oil per day.

Today, Marcus Hook ranks among the 10 largest refineries in the world and it is one of the world's most modern. It produces not only gasolines but lubricating oils, industrial oils, and many petroleum products of a specialty nature essential to war industry. With 15 Plant, which itself occupies 123 acres, the entire Marcus Hook refinery covers an area of more than 1800 acres of land. Its present throughput capacity is about 120,000 bbl. of crude oil per day. Thus, since 1901, its growth is eighty-fold. Sun's aggregate investment at Marcus Hook totals more than $60,000,000 and, in its entirety, the refinery is 100 per cent Sun financed. Of that total figure, facilities to the value of $36,000,000 are now devoted to the production of 100-octane aviation gasoline.

"Cat" Cracking

Although Sun Oil Company at Marcus Hook has contributed many pages to the annals of petroleum refining none is more noteworthy—nor herein more pertinent—than the page recording Marcus Hook as the birthplace of catalytic cracking.

Eugene J. Houdry, inventor of the process bearing his name, began his studies and research in connection with catalytic cracking in 1927. As a result of his work, the Sun Oil Company and Socony-Vacuum Oil Company became interested in the process and the combined efforts of the respective research, development, and engineering departments have developed Houdry catalytic cracking to its present commercial status.

Sun placed the world's first large commercial Houdry catalytic cracking unit on stream at Marcus Hook on March 15, 1937. Named 11-4 Plant, it was a 6-case, 1-pass system and its performance was of such high caliber as not only to confirm the soundness of the process, but to justify Sun's immediate launching of a program calling for the construction of additional units. Accordingly, two 30,000 bbl. per day Houdry combination catalytic cracking units and the world's first 2 catalytic gasoline treater units were completed by mid-1939.

One of these Houdry units, much larger than 11-4 Plant, named 12-3 Plant was constructed at the Marcus Hook refinery. This had 12 catalytic cracking cases for operation on reduced crudes. Utilizing a special treating catalyst on which the motor gasoline from catalytic and thermal cracking is vaporized and charged to a 2-case system, the already high quality of the gasoline was still further improved. In connection with 12-3 Plant, a 3-case reforming unit was designed and built in which high octane gasoline could be produced from coastal naphtha.

In December, 1940, still another—10-3 Plant, the largest Houdry unit in the world—was placed in operation. As were the other units, 10-3 Plant was originally designed to produce high octane motor gasoline and, in February, 1942, it was converted to the production of high octane aviation gasoline. Whereas the Marcus Hook refinery, before the addition of the new 15 Plant, has been noted for having the largest catalytic cracking capacity of any refinery in the world, 10-3 Plant has the distinction of having produced more catalytically cracked aviation gasoline

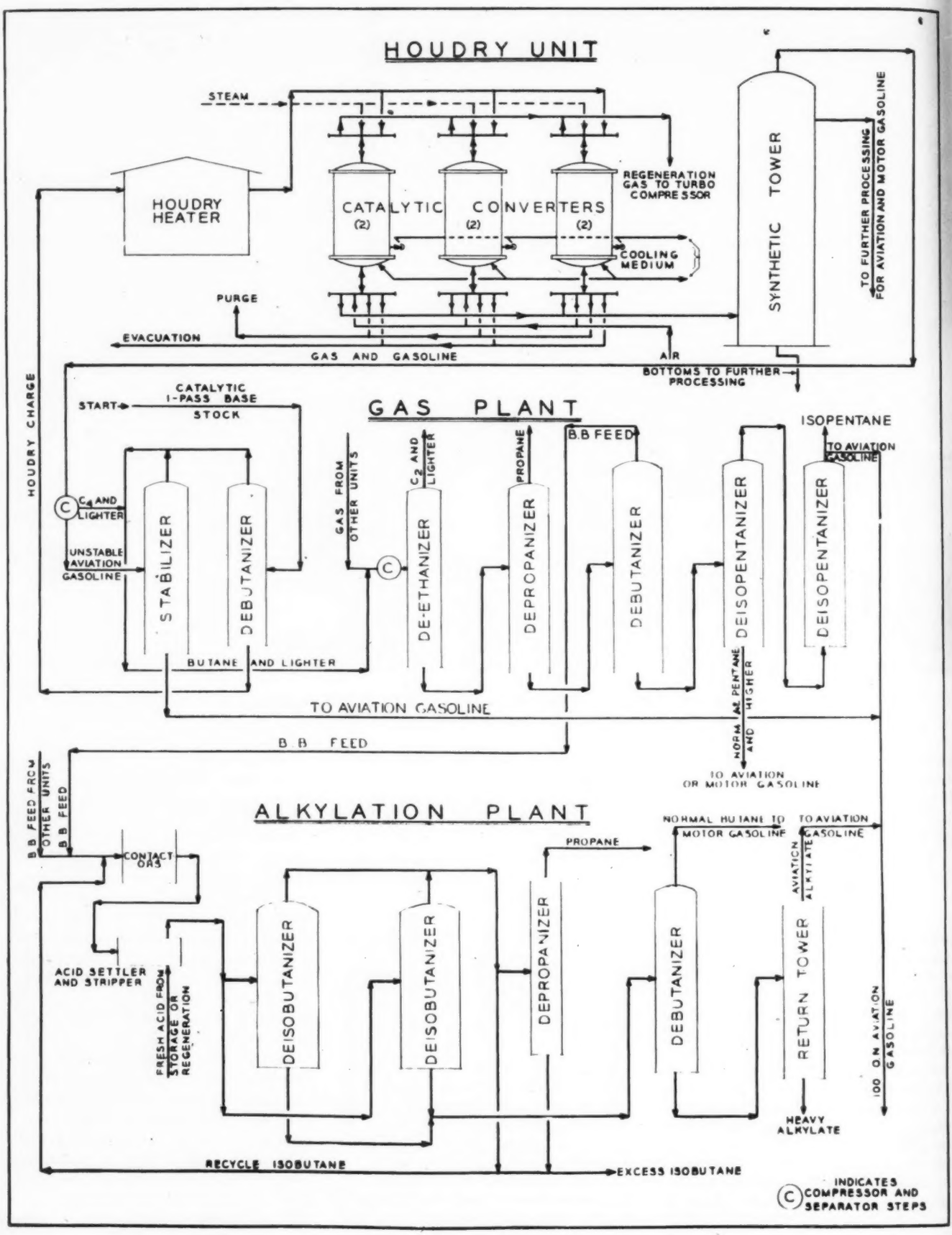


Fig. 1. Simplified flow diagram showing flow of first-pass catalytic base stock from Plant 15's gas plant through the Houdry catalytic unit to the stabilizer and further processing in the gas plant. Bottom portion of the flow plan is the HF alkylation unit, one of the largest in the world. The deisobutanizer towers are 150 ft. in height.

SUN'S NEWEST AVIATION FUEL PLANT
...now supplying 100-octane gasoline for the United Nations!
Adds to Sunoco's position as one of the world's largest producers of aviation fuel!
Yesterday Sunoco proudly dedicated a huge new aviation gasoline plant, the largest of its type in existence. In this self-contained plant, all petroleum components of aviation gasoline are produced and blended into the finest 100-octane fighting fuel.
The new plant, added to the giant facilities already in operation, makes our Marcus Hook refinery one of the largest producers of 100-octane aviation fuel in the world.
Sunoco Made Catalytic Cracking Commercially Practical
Sunoco's leadership really began long before Pearl Harbor, when the company first made commercially practical a now-famous process of catalytic cracking. No greater contribution has been made to the war effort. For, without the principle of catalytic cracking, Allied aviation fuel requirements could not have been met.
A Triumph of Private Initiative
Sunoco's entire aviation fuel program has been accomplished without government aid or subsidy. Facilities costing more than 36 million dollars are now devoted to war production in the company's Marcus Hook refinery alone. It is only through such free play of private initiative that all American progress has been achieved.
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Condensate Pumps

Naphtha Transfer Pumps

INGERSOLL-RAND refinery compressors and pumps are holding key positions in another new and vital fuel plant... one that boosts Sun's Marcus Hook Refinery output to enough 100 octane aviation gasoline to propel 2000 four-engine bombers from England to Berlin and back each week.

These pumps and compressors are heavy-duty machines that operate 24 hours-a-day, week after week. That's worth remembering when you need compressors, pumps and jets for refinery or process work.

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base stock than any other unit in existence.

Excepting 15 Plant, Marcus Hook's major refinery units for the production of 100-octane aviation gasoline consist of 4 catalytic cracking units and 1 treater. Although the new 15 Plant is a self-contained unit for production of 100-octane aviation gasoline, its function, likewise, is to link these units together taking their products, as well as products received from the combined catalytic cracking units in Sun's Toledo, Ohio, refinery, as a charge with the production of 100-octane aviation gasoline as the ultimate end product.

15 Plant's Houdry Unit

The major unit of 15 Plant, linking these facilities together, is its 6-case Houdry catalytic treating unit charged with single-pass base stock produced by the previously mentioned Marcus Hook facilities together with that received from Sun's Toledo refinery. Thus, it is a second-pass unit.

Some time ago Sun converted its original Houdry naphtha reformer unit for second-pass treating first-pass catalytically cracked base stock and commercially established the fact that second-pass treating not only increased yields but it resulted in a marked improvement in antiknock qualities. As a result, 15 Plant's Houdry unit was especially designed for second-pass treating to obtain these values.

TABLE I
Yields

Typical charge and product inspections for the treating and CTC operations are given below

No. 15 Houdry unit treating light catalytic gasoline

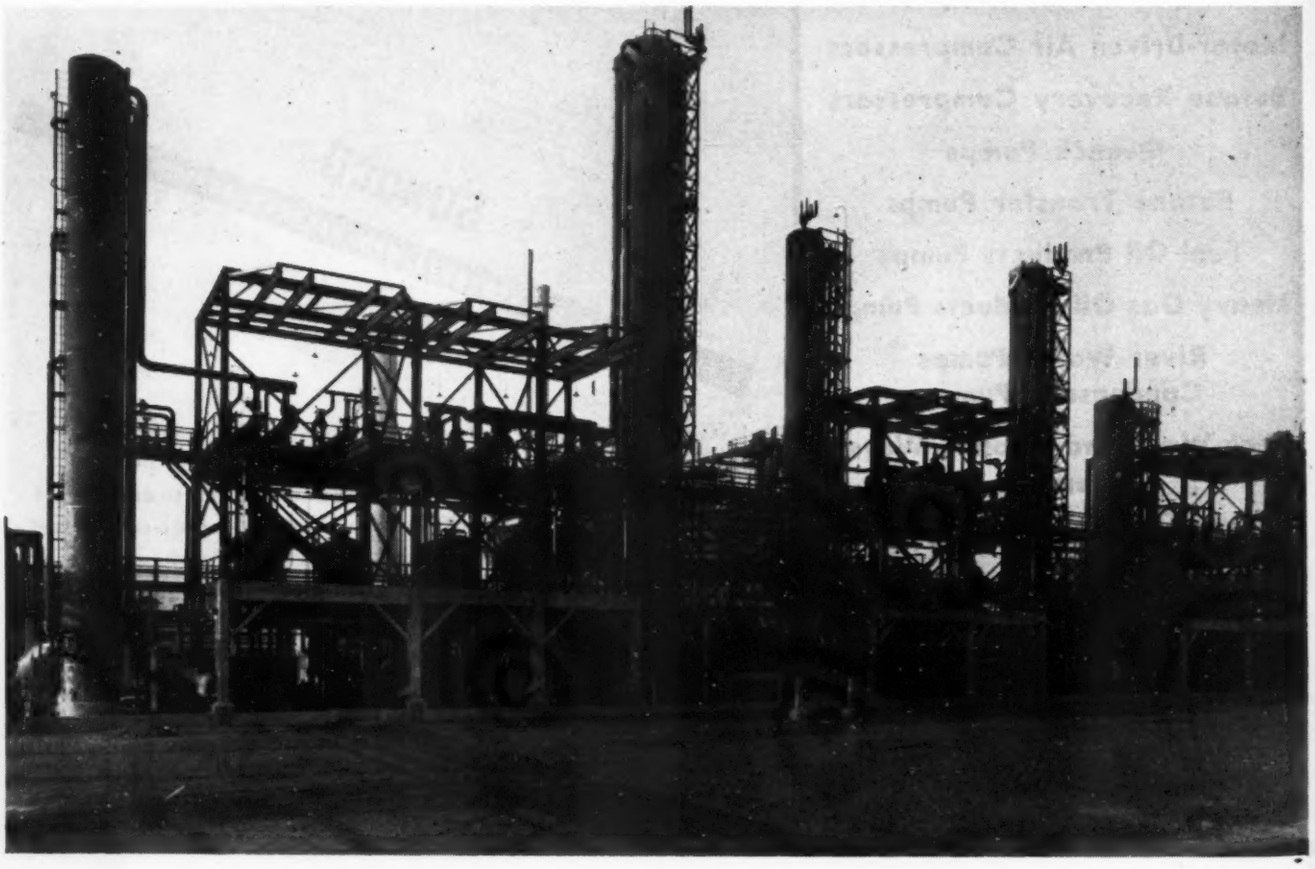
	Charge	2-Pass base	Naphtha	Bottoms
Gr.	60.4	66.0	35.7	17.2
Int.	100	100	305	359
5	119	116	313	379
10	130	122	317	381
50	211	173	334	450
90	310	276	350	610
95	328	291	360	710
EP	358	317	390	760+
Rec.	98	98	98	98
Color	16	30	29	T.D.
RVP	8.5 lb.			
Acid heat	75	9.0	6.0	
AFD1C + 4ce.	89.5	99.0		
Olefins	24	2	1	
Pod Analysis:				
C_4	1.5	0.0		
Iso C_5	16.0	30.0		
N C_5	6.0	2.1		

As shown in Fig. 1, first-pass catalytic base stock passes through a debutanizer in 15 Plant's gas plant and, as bottoms from this column, can be charged at a rate of about 20,000 bbl. per day into the Houdry unit, passing through a furnace before entering the Houdry heater where it is brought to a temperature greater than 800° F. Flow then is to the top of and downward through one of the on-stream catalytic cracking cases and thence to the synthetic tower. The overhead from the synthetic tower passes into a gas separator, the gas stream returning to 15 Plant's gas plant for further processing while the condensate is returned to the gas plant's stabilizer and then, as finished, stabilized two-pass base to blending. The unit's effectiveness is illustrated by the fact that *iso*pentane in the pentane fraction is present at a concentration of nearly 95 per cent and, in 100-octane number, equals most and is superior to some alkylates.

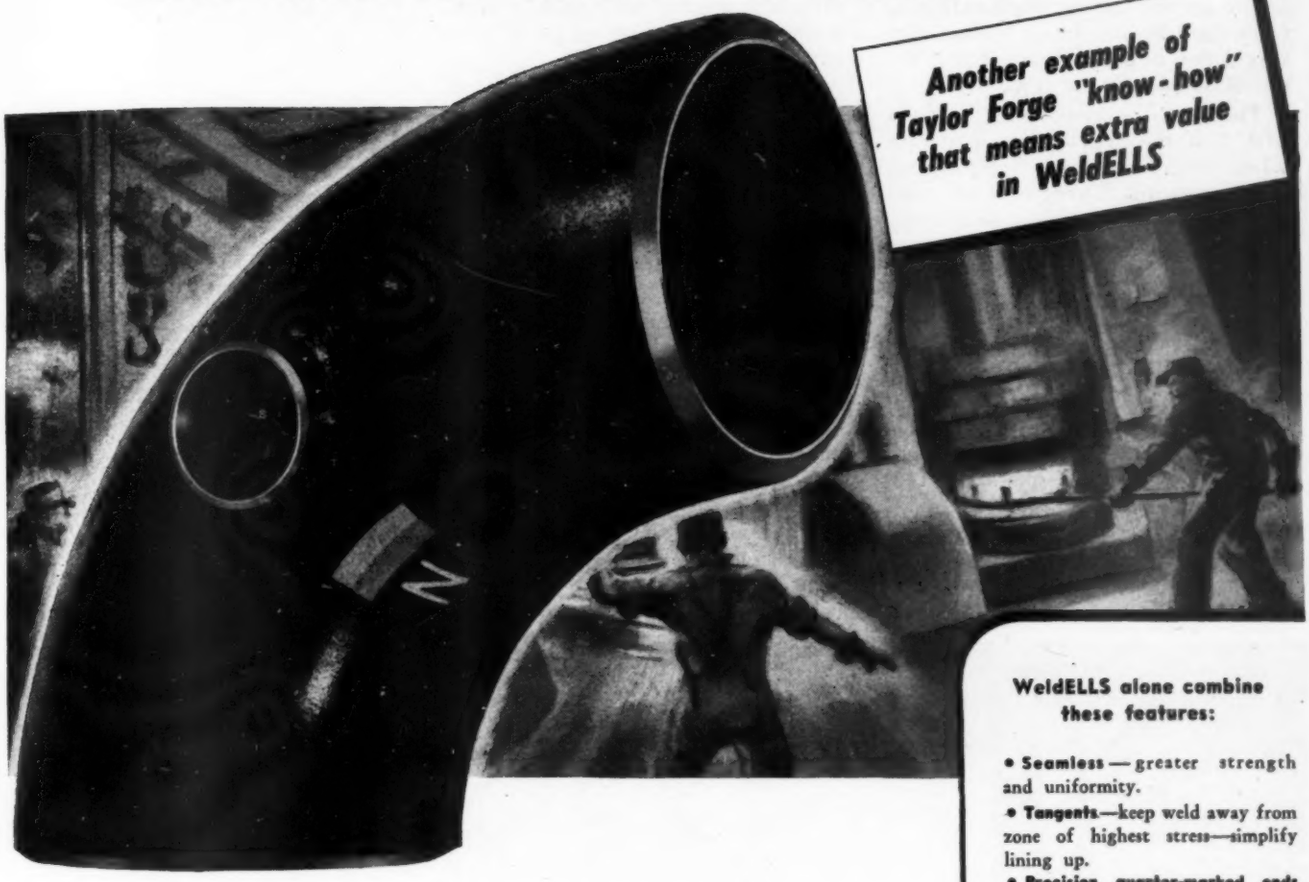
The synthetic tower's side streams, passed through a stripper, are light naphtha and No. 2 furnace oil. Heavy gas oil for further processing, is the bottoms. Arrangements are provided for recycling one or more of these substreams to the heater joining the fresh charge.

In the catalyst regeneration cycle, air flow at a rate of 40,000 cu. ft. per min. at a pressure of 45-50 lb. per sq. in. is provided by a turbo compressor energized by flue gases from the catalyst cases. In regeneration 4000 to 6000 lb. per hr. of carbon deposit are burned from catalyst particles. This results in an average steam production of 40,000 to 60,000 lb. per hr. at a pressure of 450 lb. per sq. in. at 600°F. The tempera-

Gas stabilizer and fractionation unit in Sun's new aviation gasoline plant



THIS ONE IS REALLY SPECIAL!



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But special though it is, it is simply typical of the problems that are so frequently put up to us by those who have found that we can solve them right.

Yes, doing the *unusual:* In our regular line of WeldELLS and other Taylor Forge welding fittings we have done the unusual. Into WeldELLS has gone the knowledge acquired in performing just about every conceivable kind of forging operation; knowledge of controlling hot metal under pressure and impact; knowledge that was full-grown long before welding fittings were ever produced on a commercial scale.

This is reflected in WeldELLS in features like extra metal properly distributed where stresses are greatest . . . in the tangents . . . in the extremely accurate dimensions . . . in the features, listed opposite, that are combined in no other welding fittings. Check over this list, and we believe you will agree that

WeldELLS *have everything*

WeldELLS alone combine these features:

- **Seamless** — greater strength and uniformity.
- **Tangents**—keep weld away from zone of highest stress—simplify lining up.
- **Precision quarter-marked ends**—simplify layout and help insure accuracy.
- **Selective reinforcement** — provides uniform strength.
- **Permanent and complete identification marking**—saves time and eliminates errors in shop and field.
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ture of the catalyst cases, both while on stream and during regeneration, is maintained by circulating molten salt. Circulation of the molten salt is at the rate of 36,000 gal. per min.

The 6 catalyst cases operate in pairs with 2 of the cases always on stream while the remaining 4 are purging or regenerating. Changeover of cases from on stream to purging to regenerating, with the cycle repeating 48 times per day, is automatically provided by a cycle timer that controls the operation of the various valves.

A new Houdry synthetic catalyst, especially manufactured for the production of high quality aviation gasoline base stock, is used in the cases. Each case holds 34,000 liters; the entire 6-case unit containing approximately 125 tons of catalyst.

An interesting feature of this Houdry unit is its variety of possible operations. Although it was expressly designed for and now is operating as a second-pass treater charged by first-pass catalytically cracked aviation base stock, it may also be operated on gas oil or on catalytic first-pass naphtha.

If the unit were to be operated on gas oil, throughput would be at rate of more than 10,000 bbl. per day at a space rate of 1.0 volume of oil per volume of catalyst and, on the basis of the commercial experience of other units, it is estimated that production would be 3000 bbl. per day of 93-95-octane number base stock.

Operated on catalytic first-pass naphtha, after thermal cracking, throughput capacity would approximate 8000 bbl. per day at 0.8 space rate.

As has been previously stated, the unit's present throughput capacity of first-pass base stock is about 20,000 bbl. per day but this will shortly be increased to approximately 22,000 bbl. per day, the added charge coming from a large TCC unit now being constructed at Marcus Hook. At that time the space rate will be 2.2. Data relative to the unit treating light catalytic gasoline are given in Table 1, and data concerning the unit treating catalytic first-pass naphtha are given in Table 2.

TABLE 2
No. 15-1 Plant treating C.T. naphtha

	Charge	C.T.C. base	Tower bottoms
Gr.	33.8	37.2	14.8
Int.	269	170	386
5	322	215	402
10	330	237	410
50	356	287	484
90	400	317	620
95	418	325	733
EP	436	338	760+
Rec.	98	98	98
Color	T.D.	30	
RVP		1.4	
Acid heat	32	5	
Olefins	13	1	

When planning 15 Plant, Sun looked to the future and laid out the Houdry unit so that it can be increased from a 6-case to a 12-case plant at a later date. When, as, and if this expansion takes place, 15 Plant will be equal in size to Sun's 10-3 Plant, which is renowned as the largest single Houdry catalytic cracking unit in the world.

Alkylation Unit

The tremendous volume of B-B charge material made available by the refinery's various units indicated that the inclusion of an alkylation unit as an integral part of 15 Plant would prove not only economically sound but would contribute to Sun's objective of procuring maximum 100-octane production. So great was the available volume of alkylate feed material that one of the world's largest U.O.P. HF alkylation units was designed for its processing. When the plant was designed, the availability of butylenes, in volume, made unnecessary any line segregation or the depentanization of alkylate should any lines be added to the charge material.

B-B charge to the unit is from an auxiliary pressure storage plant, complete with its own compression recovery system. The storage plant consists of seven 40,000 bbl. spheroids designed for a pressure of 20 lb. per sq. in. gauge.

This plant stores varying amounts of B-B alkylation charge, excess *iso*butane production and residual n-butane stored to meet the varying production and utilization demands imposed by the seasons. Because the Houdry catalytic cracking units produce a comparatively small volume of n-butane compared to production of butylenes and *iso*butane, n-butane is stored through summer months for use during the winter to

Close-up view of giant (150 ft.) de-isobutanizer towers of the alkylation unit

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Wagner
UNIT SUBSTATIONS

PROVIDE LOAD CENTER CONTROL FOR LIGHTING AND POWER CIRCUITS

The Unit illustrated above is installed in a synthetic rubber plant. Each transformer has a two-position liquid-filled disconnecting switch on the high-voltage side which is equipped with low-voltage interlock. The low-voltage side is equipped with air circuit breakers electrically or manually operated, ground indication lights, voltmeters, ammeters, and ammeter test blocks. Each unit has one main breaker, one tie transfer breaker, and two feeder breakers.

MOTORS
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meet the gasoline volatility requirements of cold weather.

Only slight pretreatment of the B-B charge is necessary to remove the H_2S and mercaptan present due to prefractionation of the streams from which the charge material is obtained. Therefore, only a single stage caustic wash using 15° Baume NaOH is required. This is accomplished in a 30-ft. by 5-ft., 6-in. vertical Raschig ring packed column holding 21 ft. of 1½-in. carbon rings. Caustic is circulated countercurrent over the column at a 45 gal. per min. rate until nearly spent when fresh caustic is added, the spent material being pumped to disposal. Flow from the Raschig column is through a liquid full settling tank and then, by displacement of treated B-B stock, to the drying unit.

The drying unit is a closed system eliminating loss of feed stock. It consists of 3 vertical 12-ft. by 3-ft., 6-in. chambers each containing a 10-ft. bed of activated bauxite or similar granular absorbent material. As regeneration is necessary, the chambers are in series with two functioning while the third is regenerating. In accomplishing this, the liquid is drained from the down chamber and superheated butane vapors, together with a portion of treated B-B, is passed through a condenser and to a water settling tank.

Reaction Unit

The reaction unit is composed of two complete sets of equipment, which may be used singly or concurrently. The first set, designed for parallel flow of fresh B-B and series flow of recycled *iso*butane and acid, consists of 3 water-cooled contactors. The discharge from the third contactor is to an horizontal settling tank, the acid returning for recirculation through the unit while the hydrocarbons—unreacted *iso*butane, n-butane, and alkylate—go to an operating storage tank for withdrawal into the HF stripper and defluorinator.

Three contactors, likewise, are in the second set but these are designed for parallel operation taking acid, recycled *iso*butane from the gas fractionation unit and fresh charge from the dryers. Differing from the first set, the contactors in this set discharge to their own acid settling tank with the hydrocarbons going to the common operating storage tank, which also receives those from the first set.

The total recirculation of the hydrocarbon and HF mixture through both sets of contactors is at the rate of 30,000 gal. per min. Reaction heat from the unit is removed by water circulating through tubes in the upper part of the contactors at a rate of 16,000 gal. per min., the rate of heat dissipation being 600 B. t.u. per lb. of olefin alkylated.

Fresh acid is received direct from a neighboring chemical plant through a small-diameter pipe line. Spent acid, from the acid phase of the operating storage tank, is regenerated in a stripping column. The stripper overhead is 95 per cent pure acid and its small amount of water is removed by dehydration in column with a special liner yielding an anhydrous acid.

As some dissolved HF together with some organic fluorides are present in the hydrocarbons accumulated in the storage tank, separation must occur. This is accomplished in an HF strip-

Three of the six catalytic cases of the Houdry unit at Sun's 15 Plant

per, a vertical 20-plate column operating at 20 lb. per sq. in. gauge with bottom temperature of about 200°F. maintained by a once-through type reboiler.

Feed to the stripper, from the storage tank, is over its top plate. The column is not refluxed and its overhead, containing some condensed hydrocarbons and acid, is discharged to a settling tank, the hydrocarbons returning to the feed storage tank and the acid to the settling tanks serving the parallel contactors.

For the present, the bottoms from the HF stripper, which stream is normally free of HF but contains some combined fluorides, are treated in 2 bauxite defluorinator columns, which may be operated in series or parallel, the liquid pressure being that of the HF stripper minus the normal drop. These columns are 40 ft. high and each contains a 33-ft. bed of granular bauxite, each column remaining on stream until its absorption of fluorides equals 20 per cent of the weight of its bauxite content.

Although this treatment results in 90 per cent total defluorination, an operating difficulty is experienced by the release of SiF_4 resulting from the reaction of HF on the silica content of the bauxite. This is caused, it is thought, by the decomposition of unstable fluorides and, as a compound, is carried over to the *iso*butane fractionating system by the hydrocarbon stream where it deposits as a white siliceous solid.

Later, Sun will augment the bauxite treaters with a combined HF stripper and catalytic defluorinator. Experiments in catalytic defluorination already are well under way and final development of the process will result in several benefits. As such a process will reduce the quantity of bauxite required for treatment to a minimum, not only will a substantial saving of this critical material occur, but much of the previously mentioned operating difficulty will be removed, bauxite consumption will be minimized, and the spent bauxite disposal removal problem will be substantially lessened.

Fractionation

Principal units of the fractionation section include two towering de*iso*butanizers, depropanizer, alkylate debutanizer, alkylate defluorinators, and an alkylate rerun column.

A dominant feature of the plant are two de*iso*butanizers each 150 ft. by 11 ft. Each holds 50 bubble trays spaced on 24-in. centers. Both are designed for 100 lb. per sq. in. gauge operating pressure.

The overhead vapors from the 2 towers combine in a common set of reflux condensers. An accumulator discharges 90 per cent pure *iso*butane through a split line to *iso*butane recycle in the reaction section's parallel contactors, to the unit's depropanizer or to excess storage.

In depropanizing, there is a departure from the conventional. Normally, the entire hydrocarbon stream in an alkylation plant is depropanized. In this instance, however, efficiency of prefractionating the B-B charging 15 Plant's alkylation unit makes propane removal necessary only on the stream from the de*iso*butanizer column's overhead. A single depropanizer, containing 30 trays spaced on 18-in. centers, alone is necessary for this function. Overhead from the column is to a reflux condenser and an accumulator with excess propane going to storage. Bottoms are discharged to a split *iso*butane line.

The bottom product from the de*iso*butanizer is charged to the alkylate debutanizer. This product is composed principally of alkylate and n-butane, but it contains a small quantity of *iso*butane and some trace of organic fluorides. The alkylate debutanizer holds 30 trays spaced on 18-in. centers. It operates at 90 lb. per sq. in. gauge, and the bottom temperature is 400°F. The overhead product, residual n-butane, is sent to storage.

Alkylate from the debutanizer bottom is now charged to two small, parallel alkylate defluorinators containing only ⅛ as much bauxite as the defluorinators upstream of the de*iso*butanizer columns. This secondary treatment is a precaution against decomposition of the traces of fluorides, which might be caused by the high bottom temperature of the debutanizer.

From the small defluorinators, the flow is to an alkylate rerun column containing 20 plates spaced on 24-in. centers. This column is designed for operation slightly above atmospheric pressure. The overhead, condensed, is aviation grade alkylate, which is blended with base stock from the Houdry unit and tetraethyl lead, the final product being 100-octane aviation gasoline.

Fractionation Unit

No. 15 Plant's gas fractionation and stabilization unit receives its wet gas charge from two sources. The principal source is the 20,000-bbl. Houdry catalytic gas oil unit in Sun's 10-3 plant at Marcus Hook, whereas the secondary, and minor, source is 15 Plant's own catalytic treater unit.

Before designing 15 Plant's gas recovery unit, Sun conducted a preliminary study to determine the type of gases to be handled, the magnitude of their variations and composition, and, against this data, considered several types of operations and operating conditions in order to arrive at the volume of recovery that reasonably could be expected from each. This study established the fact that the best results from the particular charge to be handled would be obtained by simple, direct fractionation of the charge at moderately high pressure.

Approximately one mile separates 10-3 Plant and 15 Plant's gas fractionation unit and, in view of the fact that wet gas and unstable gasoline from 10-3 are to be processed, these materials are subjected to an equilibrium contact operation at that point before charging to the new gas plant. The results of this operation are transmission of the lowest possible volume of wet gas to the gas recovery unit and the elimination of any major changes in the temperature and pressure conditions existing at 10-3 Plant. Table 3 details the results of equilibrium contact of the wet gas and unstable gasoline streams at 10-3 Plant.

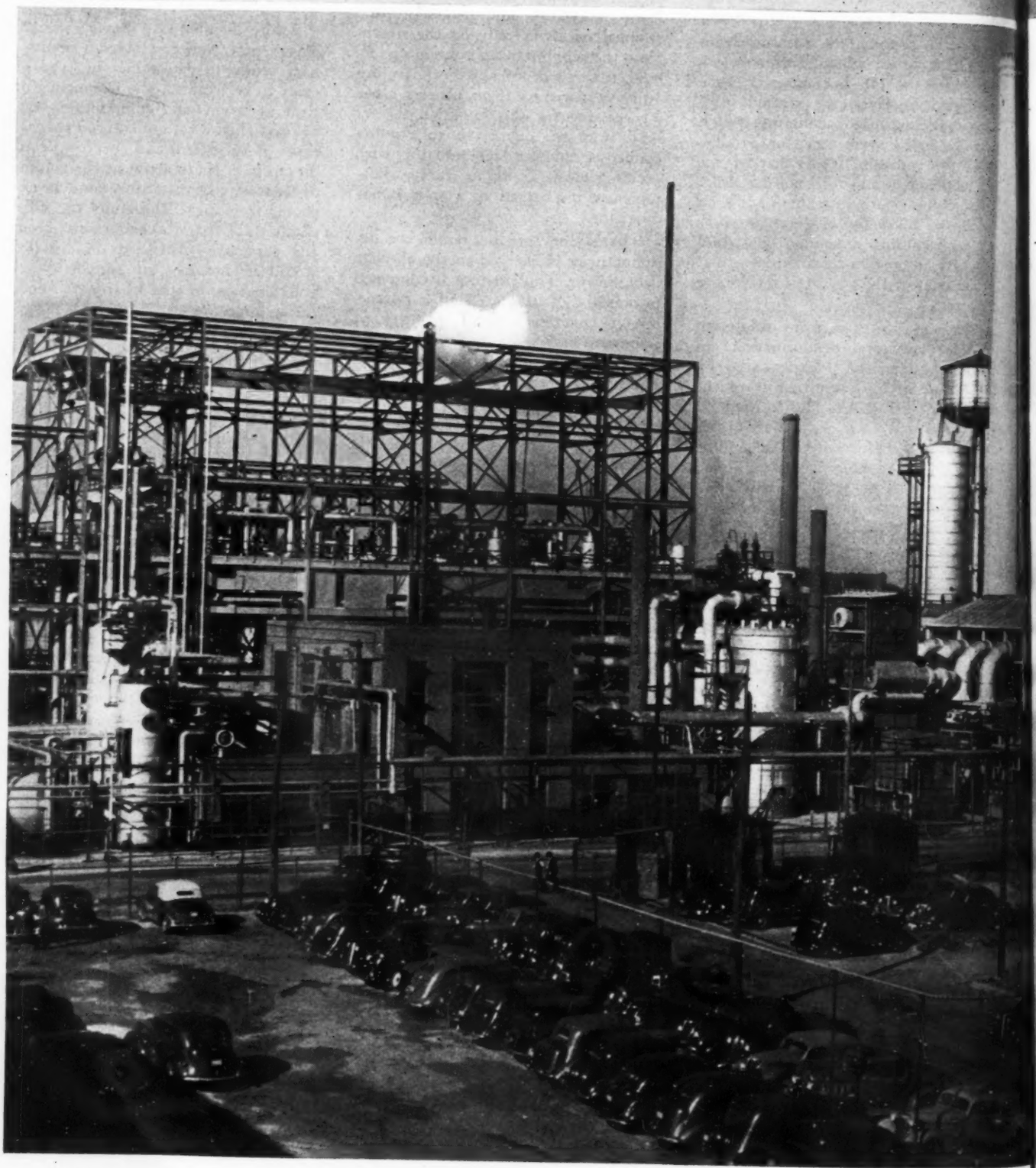
After the contacting operation, the charge from 10-3 Plant is compressed to a pressure of 50 lb. per sq. in. gauge and transmitted to 15 Plant's gas recovery unit where it is joined by the lesser charge from 15 Plant's catalytic treat-

(Continued on Page 98)

TABLE 3

Constituent	Orig. sep. pressure		After contact at 50 lb. per sq. in. gauge	
	Gas Mol per cent	Gasoline Mol per cent	Gas Mol per cent	Gasoline Mol per cent
Acid gases	5.5	....	9.8	....
Hydrogen				
Methane	11.3	0.1	19.6	0.4
Ethane-ene	6.3	0.1	9.8	0.9
Propane-ene	22.3	1.6	26.8	8.4
*Iso*butane	20.4	3.7	17.2	13.1
Butylenes	6.6	1.2	5.2	4.5
N-butane	5.1	1.2	3.7	3.7
Isopentane	10.0	5.8	4.7	10.7
N-pentane	2.1	1.6	0.9	2.6
Hexane	5.9	12.4	1.4	12.0
Heptane	2.7	15.8	0.5	11.1
Octane	1.0	17.1	0.2	10.3
Nonane+	0.8	39.4	0.2	22.3
Lb./hr.	67,517	79,470	29,738	117,349
Mols./hr.	1304.0	.....	725.1	.....

Seven years old and



d raised on bottoms!

Sun's 11-4 Houdry unit has cracked everything from refinery slop to light gas oil

An excellent demonstration of the flexibility of Houdry fixed-bed units is provided by the oldest of them all—the Sun Oil Company's 11-4 plant at Marcus Hook, Pennsylvania, which went on stream in April, 1937.

With a capacity of more than 10,000 B/D of oil to the catalyst, this was the first large-scale Houdry unit ever built to run bottoms.

From 1938 to 1941, it operated steadily on refinery residue—the 35% bottoms of all crudes processed—producing gasoline of about 90 octane (CFR research). Then, during the first year of war, it was converted to aviation fuel production, so desperately needed by our armed forces.

In 1943, this Old Faithful of catalytic cracking was still further improved, to provide even greater production of catalytic aviation base stock, a vital war assignment which it continues to fulfill with great distinction and dependability.

The ability to handle both light and heavy charging stocks is one of the outstanding advantages of Houdry Catalytic Processes. These processes and the T.C.C. Process are available to any and all American refiners, under license arrangements, subject to approval of the United States Government.

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HOUDRY CATALYTIC PROCESSES
FOR VICTORY IN WAR
FOR PROGRESS IN PEACE

(Continued from Page 95)

ing unit, which has been compressed from atmospheric to 50 lb. per sq. in. gauge. At this pressure, the combined charge is compressed in 2-stage, gas engine driven compressors without intercooling to the gas plant's operating pressure of 450-500 lb. per sq. in. gauge for discharge to the deethanizer.

Ethane Column

Conventional in type, and operated at 450-500 lb. per sq. in. gauge, the deethanizer contains 30 bubble trays spaced on 24-in. centers. The normal overhead temperature of the column is 125° F., which results in the recovery of 98 per cent plus of the *iso*butane and more than 60 per cent is fed to the unit from the column's base.

A refrigerated liquid condensate produced in equilibrium with the column's overhead residue gas in an indirect refrigerated condenser operating at about 50° F. refluxes the deethanizer. Refrigeration is obtained by drawing liquid propane from an accumulator on the downstream side of the depropanizer, vaporizing it before charging to the condenser and recovering it therefrom by an auxiliary steam driven compressor for return to the propane accumulator.

Sun considered the advisability of using refrigeration on the top of the deethanizer at length due to the possibility of gas hydrates forming. This would result, first, in irregularity in the operation of the reflux pumps and, finally, in complete loss of suction due to collection of solids in the base of the reflux accumulator. Sun discovered, however, that, although gas hydrates formed at 45° F., increasing the temperature a few degrees above that eliminated the difficulty.

Depropanizer

The depropanizer receives the bottoms from the deethanizer. This column contains 40 bubble trays. It is designed to produce commercial propane as an overhead product with depropanization resulting in a content of less than 1 mol. per cent of propane in the bottoms. Its equipment includes a kettle type reboiler, propane reflux condensers and reflux accumulator with a liquid level control by-passing propane vapors around the reflux accumulator to the propane accumulator, which discharges to storage.

The operating temperature of the depropanizer is 250 lb. per sq. in. gauge, this pressure being established by a back-pressure controller placed in the reflux condenser vapor line. The temperature of the overhead and the column's equipment are held in equilibrium, thus preventing variations in condenser-water temperature from influencing operation of the entire column.

Senate Probes Oil

A 11-man committee was named by the U. S. Senate to make a full investigation of the petroleum situation and report the results along with recommendations for the formulation of a national petroleum policy.

Senators selected are: Tom Connally, D, Texas, and Arthur H. Vandenberg, R, Michigan, from foreign relations committee; E. C. Johnson, D, Colorado, and E. H. Moore, R, Oklahoma, from interstate commerce committee; F. Maloney, D, Connecticut, and Ralph O. Brewster, R, Maine, commerce; J. C. O'Mahoney, D, Wyoming, and Chan Gurney, R, South Dakota, public lands; Robert M. LaFollette, Jr., Progressive, Wisconsin, Burnet R. Maybank, D, South Carolina, and Scott W. Lucas, D, Illinois, the three appointed by Vice President Wallace. Maloney is chairman.

B-B Fractionation

The bottoms are fed to a B-B fractionator where sharp fractionation is required to produce n-butane and *iso*butane as the overhead product and *iso*pentane as bottoms. This sharpness in fractionation is a requirement, as the overhead constitutes the principal B-B charge to 15 Plant's HF alkylation unit, whereas recovery of excess *iso*pentane over the vapor pressure requirement of the 2-pass catalytic base stock is desirable for supplementary blending.

Although this column's equipment is identical with that of the depropanizer, the operation of the reboiler is a feature of interest. While of conventional type, this reboiler operates with low pressure steam at 40 lb. per sq. in. gauge from the auxiliary steam-driven refrigeration propane compressor employed to return propane from the deethanizer condensers. The normal duty of the reboiler is 19,900,000 B.t.u. per hr. although transfer rates, on test, have been as high as 230 B.t.u. per sq. ft. per degree hour.

Split *Iso*pentane Column

An interesting feature of 15 Plant's gas recovery unit is fractionation of *iso*pentane in 2 columns that operate as a single column. The split was made necessary by the fact that the required height of a single column would have been too great for the shell thickness and increasing shell thickness would have required additional steel badly needed by the war program.

The columns are operated in series. Vapors from the top of the first column are fed into the base of the second. Liquid from the bottom of the second column is pumped back to the top of the first. Each column is 80 ft. high and contains 30 bubble trays spaced on 24-in. centers.

The overhead of the second column is *iso*pentane approximating 98 per cent pure and may be charged to 15 Plant's Houdry catalytic treater, blended in 100-octane aviation gasoline or the excess *iso*pentane may be made available to refineries where *iso*pentane deficiency exists.

Stabilization

The stabilization section in 15 Plant's gas recovery unit consists of a debutanizer charged by single-pass base stock from 10-3 Plant's gas oil unit and a stabilizer charged by second-pass base stock from 15 Plant's Houdry catalytic treater.

The charge to the debutanizer is unstable gasoline that has been subjected to the equilibrium contact operation in 10-3 Plant. Table 3 details its composition after contact. This material is debutanized before charging to 15 Plant's Houdry catalytic treater. The function of the stabilizer is to restabilize the second-pass base from 15 Plant's Houdry unit for positive maintenance of its composition and quality.

The debutanizer operates at 185 lb. per sq. in. gauge. This pressure was selected because it was decided to operate the column so that a large portion of the overhead would be obtained as a liquid, thus eliminating recompression of large volumes of vapors. At 185 lb. per sq. in. gauge the operating pressure, however, is still low enough for reboiler operation with 450 lb. per sq. in. gauge steam. As the source of the charge is 10-3 Plant located a mile distant, a feed tank is provided to take up production surges. To facilitate the subsequent fractionation of the column's overhead, a similar surge tank is also provided. The column contains 30 trays spaced on 18-in. centers.

Second pass base stock from 15 Plant's Houdry unit is charged to a feed surge tank before entering the stabilizer. This column contains 30 trays spaced on 18-in. centers and operates at a pressure of 175 lb. per sq. in. gauge for reasons similar to that influencing the operating pressure of the debutanizer.

The overhead from the debutanizer and the overhead from the stabilizer are fed to a common accumulator and thence to the gas recovery plant's deethanizer. The bottoms from the stabilizer is stabilized aviation gasoline base for blending with alkylate and tetraethyl lead for final production of 100-octane aviation gasoline.

——— ☆ ☆ ☆ ———

Corrosion of Buried Metals And Cathodic Protection

PART 2

by M. C. Miller

Electrical Engineer, Ebasco Services Incorporated

THERE may be considerable difference in type of soil, foot by foot, along a pipe line due to a number of reasons. In some areas, the type of soil changes frequently along a pipe line because of the construction of the earth. In digging the trench for a pipe line, it may go down through layers of different types of soil and in backfilling these are mixed together around the pipe and may cause considerable corrosion. Metal structures may be buried in land that has been reclaimed by filling with numerous kinds of soil. Figs. 13, 14, 15, and 17 show these conditions and direction of current flow in each case.

Cinders usually cause serious corrosion. This is due to two conditions: Where the cinder contacts the metal, electric currents of considerable magnitude may be produced, with the direction of flow as shown in Fig. 16. When cinders are mixed with the soil over the buried metal, acid from the cinders may be carried by water downward through the soil to the surface of the metal with accelerated chemical action and corrosion. This is shown also in Fig. 16.

Scarring of the surface of a metal may result in rapid corrosion. Threading of a pipe, or cuts made by teeth of a pipe wrench, expose bright metal that then acts as a dissimilar metal compared to the other surface with current flowing from and corrosion occurring at the bright metal, as shown in Fig. 19. This is a common occurrence. In many cases the wall of a pipe may be corroded through at these threads and wrench marks, whereas the balance of the pipe surface still is in good condition.

In the opening paragraphs, it was stated that the electric current causing corrosion, which flows from a metal into the soil, flows through the soil and to the metal at some other location. The length of the path the current takes through the soil may be a few inches as indicated in Figs. 15, 16, 17, 18, 19, and 20, or the path may be a foot, 100 ft., 1000 ft., or a mile or more, as indicated in Figs. 1, 8, 9, 10, 11, 12, 13, 14, and 20. As indicated in the drawings, current may flow from the surface of a metal at one or more areas and to the surface of the same metal at other areas.

When dissimilar metals are used and are connected together, the current flow results in corrosion of one of the metals, but the amount of current that flows may not be sufficient to stop entirely corrosion on the other metal, viz., a galvanized pipe and a black iron pipe may be connected together with resulting flow of current and corrosion of the galvanized pipe. The amount of current flowing from the surface of the galvanized pipe through the soil and to the surface of the black iron pipe may not be sufficient to reach all the surface of the black iron pipe, and soil conditions, scars or threading on the black pipe may still cause corrosion of the black pipe.

Additional electric current can be supplied from some external source to force current to flow to the entire surface of a buried metal and thereby stop corrosion. This additional current may be supplied by some other dissimilar metal buried in the soil and connected to the pipe. Zinc plates are used extensively for this purpose, as shown in Fig. 21, or the additional current required may be supplied by a rectifier (which converts alternating current into direct current that is required) or an engine or wind-driven electric generator or electric battery. Fig. 22 indicates the current flow using a rectifier. Whether the additional current is supplied by zinc (or other dissimilar metal buried for that purpose) or by rectifier, battery, or generator, this means of reducing or stopping corrosion is called cathodic protection.

Fundamentals of corrosion. A good understanding of the fundamentals of galvanic corrosion may be obtained by comparison with a common dry cell (commonly referred to as a flashlight or dry battery).

Some may think a dry cell is made by building a container and putting into it a certain amount of electricity to be

(Continued on Page 105)

Fig. 13. Corrosion caused by dissimilar soils

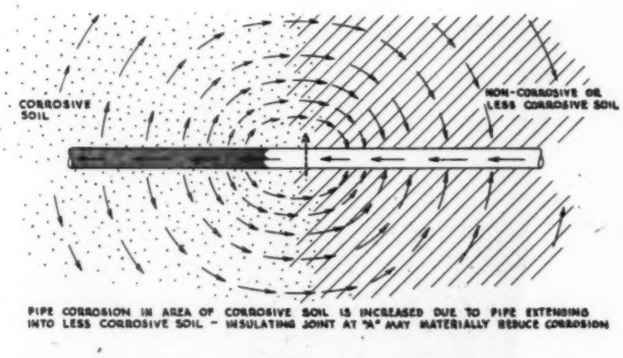
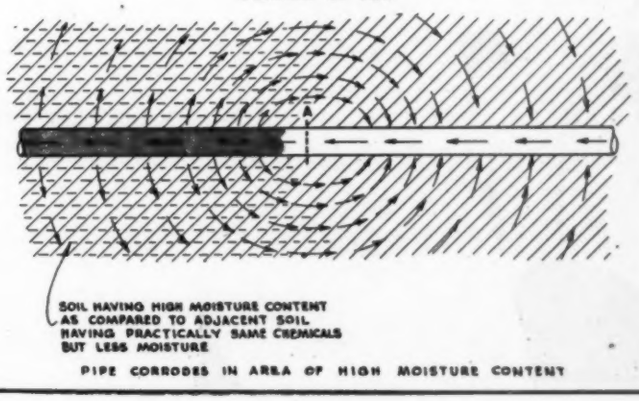

CORROSIVE SOIL
NON-CORROSIVE OR LESS CORROSIVE SOIL
PIPE CORROSION IN AREA OF CORROSIVE SOIL IS INCREASED DUE TO PIPE EXTENDING INTO LESS CORROSIVE SOIL - INSULATING JOINT AT "A" MAY MATERIALLY REDUCE CORROSION

Fig. 14. Corrosion caused by difference in moisture content of soil


A
SOIL HAVING HIGH MOISTURE CONTENT AS COMPARED TO ADJACENT SOIL HAVING PRACTICALLY SAME CHEMICALS BUT LESS MOISTURE
PIPE CORRODES IN AREA OF HIGH MOISTURE CONTENT

Then he said to himself

"THIS WAR HOLDS UNPREDICTABLE DEVELOPMENTS"

FOR once Premier Mussolini was right when, just a year ago, he warned the Fascist Directorate that "This war still holds unpredictable developments, which will not all be on the political plane."

But there was enough on the "political plane" to slam his chin back in his collar, and if one wishes to read a moral into his statement, it could well be:

You always lead with your chin when you team up with the wrong working partner.

It is then you get unpredictable results of a DESTRUCTIVE nature.

(Continued from Page 101)

drawn out at will until it is used up. Most of us know that such is not the case — that all the electricity obtained from a dry cell is generated *within the cell at the instant it is used* and that this current is the result of chemical actions between the metals, materials, and chemicals contained in it. When these metals and materials are used up, or chemically changed in nature, the dry cell will generate little or no current and usually is thrown away.

In its simplest form, a dry cell consists of a container of zinc and a center post of carbon, with the balance of the space filled with chemicals that form an electrolyte; the combination constitutes an electrical generator. This is shown in Fig. 3. When a wire, lamp, or other load is connected between the two exterior terminals, an electrical circuit is established and current flows, as shown in Fig. 4. This is direct current.

In order to explain the dry cell more fully and to show how the current generated is analogous to the current generated by metals corroding in soils, it is necessary to make use of a few electrical terms, which are listed and explained below, although these probably are familiar to most people.

Potential is the electrical pressure. It is measured in volts.

Current is the electricity flowing. It is measured in amperes or milliamperes. One (1) milliampere is 0.001 ampere.

Electrode is a metal, material, or other current-conducting medium in contact with an electrolyte by which current flows from or to the electrolyte. An electrode may be either an anode or a cathode.

Anode is the metal or material, or the area on a metal or material, from which the current flows into the electrolyte. It is the negative (—) electrode of a dry cell.

Cathode is the metal or material, or the area on a metal or material, to which the current flows from the electrolyte. It is the positive (+) electrode of a dry cell.

Electrolyte is the current-conducting solution between the anode and cathode. It may be a chemical solution of liquid or paste, water, soils, or combinations of two or more of these.

Resistance is a measure of the extent to which an electrolyte, soil, wire, etc., which make up the electric circuit, retard the flow of electric current. It is measured in ohms. For wire, the resistance is expressed in "ohms per 1000 ft. or per mile." For electrolytes, such as soils and water, the resistance usually is expressed in "ohms per centimeter cube," which is the resistance between two faces of a centimeter cube of the electrolyte.

The common dry cell when new has a potential of approximately 1.5 v. between the negative and positive terminals, which are the exterior terminals of the anode and cathode, respectively. This is a static potential with no current flow. (See Fig. 3.) When a wire, lamp, or other load is connected between the terminals, a current flows through this external load. The direction of flow through the wire, lamp, or other load is from the positive (+) to the negative (—) terminal. The current that flows through the external circuit and load is generated inside the battery by the chemical action between the anode and cathode materials and the chemicals that form the electrolyte. Inside the cell, as shown in Fig. 4, the direction of current flow is from the anode (or negative electrode) into the electrolyte, through the electrolyte and onto the cathode (or positive electrode). In this chemical action, the anode goes into solution or, as is commonly referred to, is corroded, until chemical action dies out and no more current can be obtained.

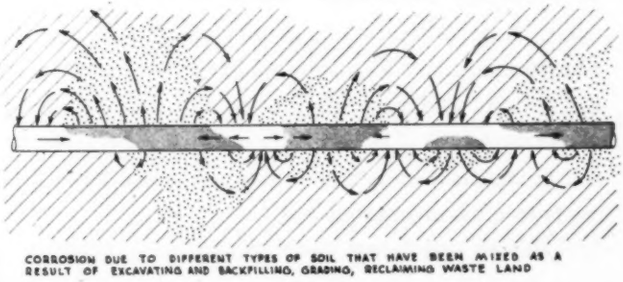
The amount of current, or amperes, that will flow depends on three principal factors:

1. the potential between terminals,
2. the internal resistance of the cell,
3. the resistance of the external load circuit.

For the usual dry cell, the internal resistance is quite low, and if a short is placed between the terminals, a relatively large current will flow. For a standard No. 6 dry cell, this may be in the order of 30 amp. for a few seconds. For a large-size flashlight cell, the current may be about 10 amp. for a few seconds. This is of especial importance in connection with corrosion of buried metals because the galvanic cell formed by the metals and soils are short circuited. Fortunately, higher resistance of the soils and effects of polarization reduce the magnitude of galvanic current flow to and from buried metals.

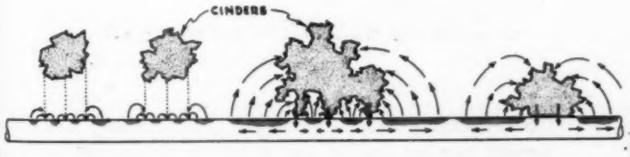
The potential of a dry cell depends on the metals or materials used for the container, which is the anode or negative electrode, and for the cathode or positive electrode; also on the chemicals that go to make up the electrolyte. If, instead of using zinc for the anode,

Fig. 15. Corrosion caused by mixture of different soils



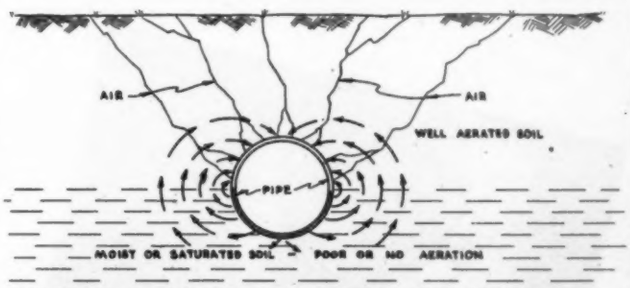
CORROSION DUE TO DIFFERENT TYPES OF SOIL THAT HAVE BEEN MIXED AS A RESULT OF EXCAVATING AND BACKFILLING, GRADING, RECLAIMING WASTE LAND

Fig. 16. Corrosion due to galvanic action of cinders and acid from cinders



CINDERS IN THE SOIL MAY CAUSE SEVERE CORROSION IN TWO WAYS:
(1) DIRECT CONTACT, SETTING UP ACTIVE GALVANIC CELLS
(2) SULPHURIC ACID FROM CINDER ABOVE PIPE CARRIED DOWN THROUGH THE SOIL TO PIPE SURFACE BY SOIL WATERS

Fig. 17. Corrosion caused by differential aeration of soil



IF AIR DRIES SOIL AT TOP OF PIPE BUT NOT AT BOTTOM, DIFFERENCE IN MOISTURE IN SOIL RESULTS IN CORROSION AS INDICATED ABOVE. DRY SOIL CHANGES METAL-TO-SOIL POTENTIAL MAKING IT LESS NEGATIVE - THIS RESULTS IN GREATER DIFFERENCE IN POTENTIAL BETWEEN BOTTOM AND TOP OF PIPE WHICH TENDS TO INCREASE CURRENT FLOW AND CORROSION. ALSO, AIR REACHING TOP OF PIPE TENDS TO DESTROY POLARIZATION WHICH OTHERWISE WOULD TEND TO REDUCE CURRENT FLOW AND CORROSION.

Fig. 18. Corrosion due to impurities in surface of pipe

CORROSION CAUSED BY SMALL PARTICLES OR IMPURITIES IN SURFACE OF PIPE - IF THESE ARE ANODIC TO BALANCE OF SURFACE AND ARE SMALL IN AREA CONCENTRATED CORROSION OR PITTING RESULTS IN CORROSIVE SOILS

The Latest Development

in a Mechanical Joint for Cast-Iron Pipe

The "All-in-One"

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Bellmaster Joint

As cast-iron pipe again becomes available, you naturally take keen interest in a faster and better method of joining it. The compact, tight, flexible Dresser Bellmaster Joint, Style 85, offers you both speed and efficiency.

In the Bellmaster, Dresser engineers have developed a mechanical joint of amazing simplicity. Each joint consists of a resilient rubber-compound gasket compressed by capscrews between two light, strong malleable iron rings. It is shipped, stocked and installed completely assembled.

The Dresser Bellmaster makes up tight and stays tight. Automatically absorbing expansion, contraction, deflection and vibration to an unusual degree, it cushions and protects the pipe while maintaining a constant seal. Locked within the bell of the pipe, it is completely enclosed. No outside lugs, no exposed parts to chip or corrode.

Investigate this latest development in a mechanical joint for C I P. Makers can supply Bellmaster pipe, and we are able to ship joints promptly. Sizes—3", 4", 6", 8", 10", 12" and 16".

Catalog 413 ARM on request.

Your workman has only one piece to handle — even the newest man on the job can make up tight joints in from two to five minutes with the Dresser Bellmaster.

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magnesium is used, the potential will be about 3.0 v. If copper is used, it will be about 0.5 v. If, instead of using carbon for the cathode (or positive electrode) copper is used, the potential will be about 1.0 v. A different chemical or solution could be used for the electrolyte to obtain a different potential.

It is apparent that a dry cell, having a potential of from 0.1 v. or less, up to about 3.7 v., may be made by using different metals; viz., if gold instead of carbon were used for the cathode or positive electrode and magnesium instead of zinc were used for the anode, or negative electrode, the battery potential would be about 3.7 v. For the metals commonly used in underground construction — copper, lead, cast-iron, steel, zinc-coated (or galvanized) steel, the potentials of the galvanic cell created by these metals in soils are in the lower ranges from 0.1 v. and less up to about 1.0 v. But considering the physical size of these buried metal structures, as compared to a dry battery, and that they are short circuited, it is apparent that relatively large currents frequently will exist and cause serious corrosion.

Each metal (and some materials such as carbon) when placed in an electrolyte, such as soils or water, has an electro-chemical potential to that electrolyte. It is different for different metals and different electrolytes. This may be considered a half-cell potential, as two of these "half-cells" are required to make up a dry cell. The half-cell potentials for a number of common metals (in an established standard solution containing a specific amount of salts of the same metal) are listed in the box on this page.

In solutions and soils containing different chemicals and salts, these half-cell potentials may change appreciably as compared to the above electro-chemical potential series, and the potential of a few of these metals may reverse position with respect to potential of other metals. Therefore, in field measurements, the potentials of these metals as measured to a copper-sulphate reference electrode vary over a wide range and differ from the values listed.

Electro-positive or noble metals	*Half-cell potential in solution of own salts** (potential to a hydrogen reference electrode)
Gold	+ 1.36 to 1.5
Carbon	+ 0.90
Platinum	+ 0.86
Silver	+ 0.80
Mercury	+ 0.80
Copper	+ 0.34 to 0.47
Copper sulphate electrode	+ 0.34
Hydrogen—as a reference electrode	0.0
Electro-negative or base metals	
Lead	— 0.12
Tin	— 0.14
Iron	— 0.05 to 0.35
Rusty steel	— 0.25 estimated
Bright steel	— 0.45 estimated
Zinc	— 0.77
Aluminum	— 1.7
Magnesium	— 2.4

*From handbook "Physics and Chemistry" 1943, p. 1368.

The hydrogen reference electrode is used in laboratory work. It has not been developed for practical field use. The copper-sulphate electrode is used extensively in the field in connection with corrosion investigations and cathodic protection of pipe lines and other metal structures. Lead electrodes generally are used in connection with corrosion investigations and cathodic protection of lead-sheathed cables. The reasons for using these are explained later.

The potential between any two metals in an electrolyte will be the difference between the half-cell potential of each as measured to some stable reference electrode. The more negative metal will be the anode or the metal that will corrode if the two are connected together in an electrolyte. (See Fig. 5.)

The surface condition of a metal, such as rust on the surface, mill scale, a polarization film, also the type and condition of the soil or other electrolyte, materially change the half-cell voltage.

All the foregoing is similar to what takes place when metals are buried in soils or other electrolytes, such as sea water.

As a simple experiment, drive a copper rod and a galvanized rod a few feet apart in damp corrosive soil. With a suitable voltmeter connected between the two rods, measure the voltage. It probably will be about 1 v. If reference electrodes are available, measure the metal-to-soil potential of each and see whether the difference between the two equals the voltage measured between the two. It will, if suitable reference electrodes and meters are used. Connect the two through a low-resistance milliammeter and note the current flow and the direction of current flow through the meter, which constitutes the external circuit. Note that the metal that measured more negative to the reference electrode is the negative electrode of the galvanic cell and therefore the anode or corroding metal.

Try this with different metals and in different soils. The results are enlightening and well worth while to one who desires to understand the fundamentals of corrosion and cathodic protection.

Fig. 6 shows a test installation of pipe (approximately 2 in. by 12 ft.) in corrosive soils and the potential of each measured to the copper pipe and to a reference electrode (copper-sulphate electrode); also, to the potential measured between pipes.

Fig. 7 shows the galvanic current in amperes and the calculated amount of metal that this current would carry away per year. Note the direction of current in the meter or external circuit and through the soil. (The amount of current flow was reduced by the 10-ohm resistance in the external circuit. If a low-resistance ammeter, with an internal resistance of about 0.005 ohms, had been used the current would have been about double that shown).

These simple tests can be made by anyone in a few hours time, and are well worth the effort. With the same pipes,

(Continued on Page 110)

Fig. 19. Corrosion caused by scarring and threading of iron pipe

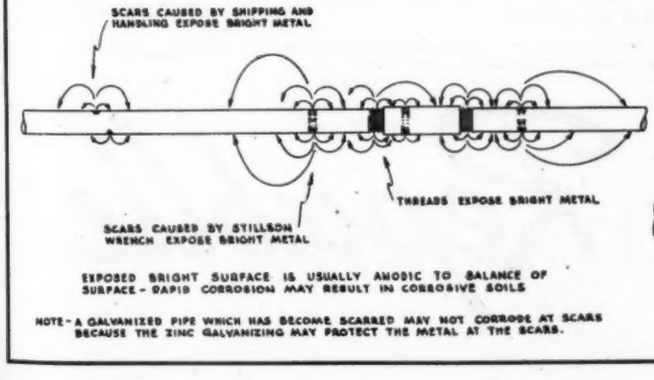
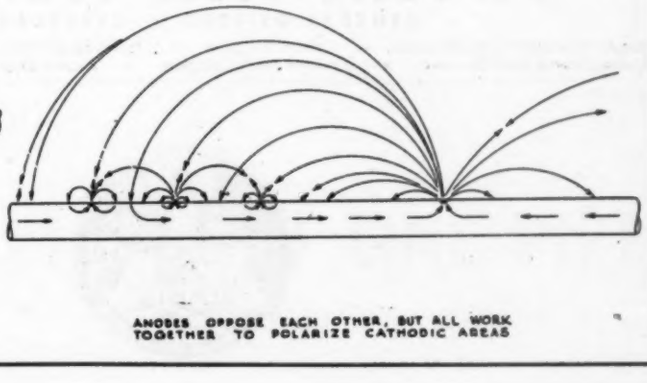

SCARS CAUSED BY SHIPPING AND HANDLING EXPOSE BRIGHT METAL
THREADS EXPOSE BRIGHT METAL
SCARS CAUSED BY STILLSON WRENCH EXPOSE BRIGHT METAL
EXPOSED BRIGHT SURFACE IS USUALLY ANODIC TO BALANCE OF SURFACE - RAPID CORROSION MAY RESULT IN CORROSIVE SOILS
NOTE - A GALVANIZED PIPE WHICH HAS BECOME SCARRED MAY NOT CORRODE AT SCARS BECAUSE THE ZINC GALVANIZING MAY PROTECT THE METAL AT THE SCARS.

Fig. 20. Reduction in corrosion due to bucking effects of anodes



150,000 Miles

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Every day, brave men and women in the occupied countries of Europe risk their lives to carry on "underground" activities that harass and infuriate their conquerors.

Here in America is an "underground", too—one absolutely vital to the successful progress of our war effort.

It is an underground of steel—some 150,000 miles of trunk and transit pipe lines, and many thousands more of gathering and distribution lines.

Through it *in safety* flow crude oil to refineries, gasoline and petroleum products to distribution terminals, natural gas to points of consumption.

MORE THAN 30,000 MILES OF THIS "UNDERGROUND" IS REPUBLIC ELECTRIC WELD LINE PIPE

Back in 1929, Republic Steel began to produce line pipe by a new, distinctive process of electric welding. Soon thousands of miles had been put into service—and before long it had proved its safety and economy as a transportation medium.

Look at its record for dependability in the longest gasoline line in the world—stretching all the way from Hobbs, N. Mex., to Chicago, Ill. About 700 miles of this 8⅝" line was installed back in 1931 between Borger, Texas and St. Louis, Mo. Eight years later, it was extended to Chicago—and still later to Hobbs.

Of particular interest is the fact that it continues to afford the trouble-free service for which this pipe is noted—even while working under pressures *several hundred pounds higher* than that for which it was designed.

Republic *Electric Weld* Line Pipe and companion products made by the same time-proved process have established many more records during years of actual service. Some 50,000,000 feet of Republic *Electric Weld* Casing and Tubing are in use. And more than 120,000,000 feet of Electrunite Boiler and Heat Exchanger Tubes made by Republic's Steel and Tubes Division have been installed.

We shall be glad to tell you about them—and to send you a copy of the book, "The Pipe of Progress." In it you will find an interesting pictorial description of the Republic process, the rigid controls and the *hourly* tests made to insure as close to 100% successful performance as human ingenuity and control can produce.

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REPUBLIC STEEL — PRODUCTION FOR VICTORY

Republic

of "Underground"

"LINE-TESTED" ELECTRIC WELD LINE PIPE

(Continued from Page 107)

numerous simple but enlightening tests can be made to show the fundamentals of corrosion and cathodic protection. These may be used also to investigate many of the more complex problems involved in application of cathodic protection to buried metal structures.

Corrosion caused by dissimilar metals. With copper wires and pipes, lead-covered cables, cast-iron and steel pipe, galvanized pipe and conduits, and other metals buried in the earth, many of which are connected, millions of galvanic cells are created. The result is an enormous cost of corrosion annually due to the corrosion of metals caused by the galvanic currents generated.

A large part of this corrosion may be the result of indiscriminate use of dissimilar metals, or electrically connecting dissimilar metals where it might be avoided.

Consider a commonly used installation of an uncoated galvanized service pipe connected to a cast-iron or steel main, either water or gas. In corrosive soil, this constitutes a galvanic cell that would have an open circuit potential of about one-half to one volt. With these electrically connected in corrosive soil, the galvanized pipe might be corroded beyond repair in a relatively few years. This is not theoretical; it is an everyday occurrence. Fig. 8 shows the direction of current flow. The amount of current that flows depends on the resistance and character of the soil, the relative area of the anode and cathode, the amount of current the cathode may be receiving from other anodic structures, and other factors discussed later. For each ampere that flows from the galvanized pipe, 20 to 25 lb. of metal a year are lost. If this current flow from the anode is concentrated at a few small areas, a hole in the pipe may occur in a couple of years under severe conditions.

A few of the commonly used combinations of dissimilar metals are shown in Figs. 9, 10, 11, and 12.

New Oil State Looms

Arizona may be the third state added this year to the list of those with oil production. Florida and Alabama have each had oil discoveries.

Testing of a saturation is being made at the Union Oil Company of California and Continental Oil Company No. 1 New Mexico-Arizona Land Company, SWC NE 34-15n-19e, in Navajo County, Arizona. The wildcat was drilled to 3607 ft. and plugged back to 1700-80 ft. for testing.

It is obvious that considerable reduction in corrosion of buried metals may be made by breaking up these galvanic cells, which are due to electrically connecting dissimilar metals in corrosive soils.

Dissimilar metals buried close together but not electrically connected may have some slight corrosive effects on each other or one on the other. However, the effects probably are extremely small compared to the corrosion that would result from electrically connecting them.

Corrosion caused by dissimilar soils. Probably a large percentage of corrosion of buried metals is the result of galvanic currents generated because of dissimilar soil conditions—the amount and kind of chemical salts contained in the soil, moisture content, electrical resistivity, and amount of air. There is little that can be done about this except to protect the pipe or metals adequately with a good protective coating. In some cases, viz., where a pipe line extends through short areas of highly corrosive soils, the installation of insulating couplings at each end of the corrosive areas may be desirable, but might be harmful if improperly located. Figs. 13, 14, 15, 16, and 17 indicate some of the soil conditions that cause corrosion.

There are so many ramifications of corrosion due to soils, that no attempt is made here to go into detail on the subject. Many corrosion engineers believe that soil conditions are the predominant factor in corrosion. This may be correct.

For anyone desiring to study the many effects of soil chemicals, moisture, aeration, shrinkage, and pH value, a paper prepared by the Bureau of Standards, Underground Corrosion Section, is suggested for reading.* It summarizes the results of extensive corrosion tests and soil analysis and correlation of soil characteristics with corrosion as measured by pit depths on buried samples.

Corrosion caused by non-uniformity of metals. Metals commonly used for underground structures are made up of a mixture of different kinds of ores and metals. Particles of these may appear in the surface of the finished metal. When buried in soil, these particles may have a different potential to the soil than other particles or the general surface of the metal. These then act like dissimilar metals and set up galvanic cells. If these particles are small in comparison to the surface of the metal and the potential is such that they are anodic to the other surface, rapid corrosion may result in corrosive soils, with the corrosion being concentrated at these small particles causing deep pitting—frequently causing small diameter holes through a pipe although most of the surface is in good condition. Fig. 18 indicates the galvanic action caused by these particles of metals.

Editor's Note: This article will be continued in an early issue of *The Petroleum Engineer*.

*A copy of this paper "Corrosion in Soils," U. S. Department of Commerce, National Bureau of Standards, Letter Circular LC689, dated April 22, 1942, may be obtained from the National Bureau of Standards, Washington, D. C.

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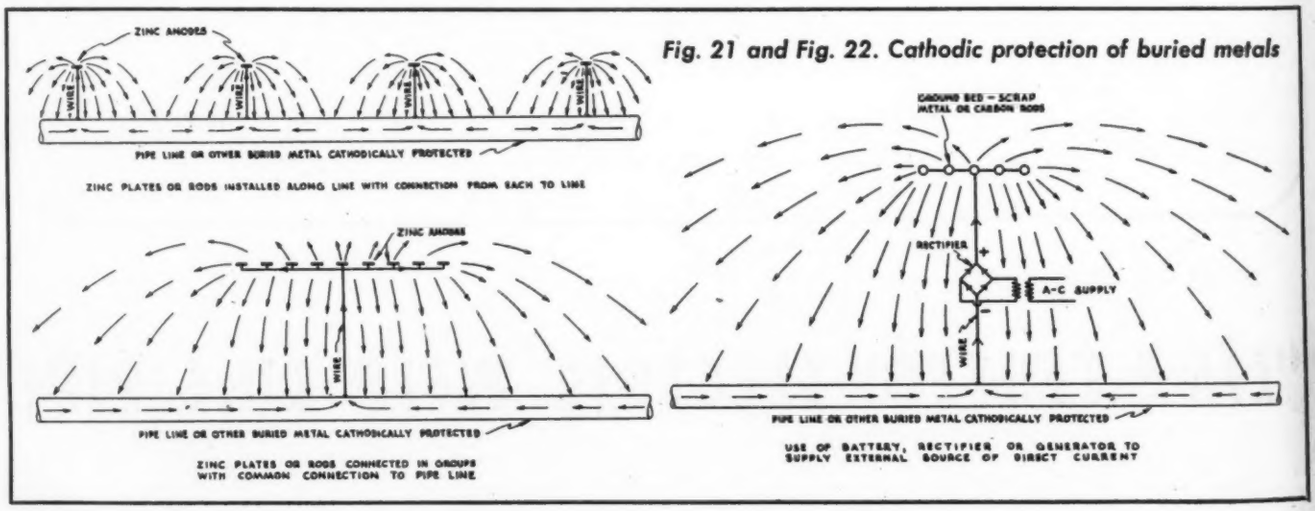
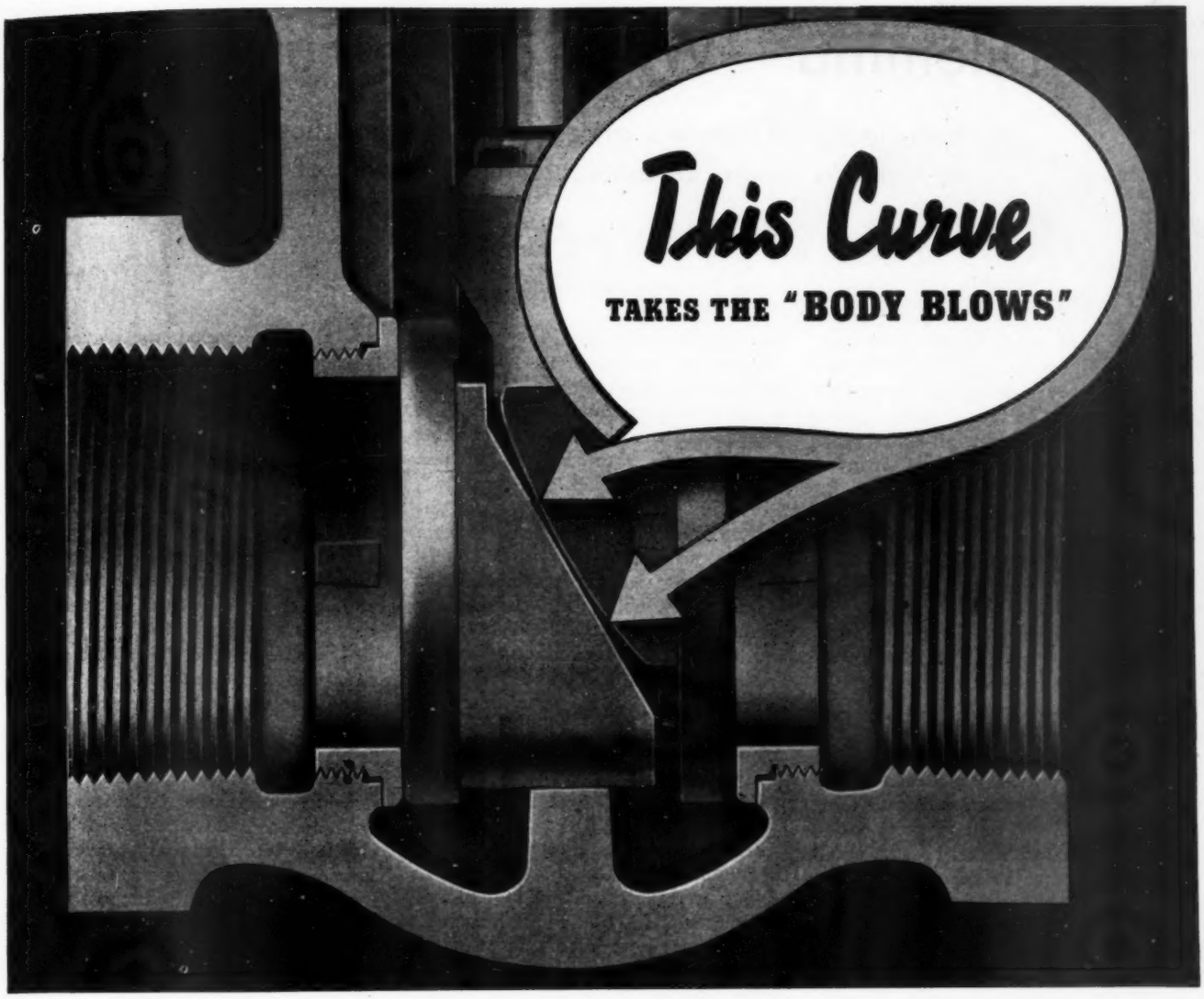

ZINC ANODES
WIRE
PIPE LINE OR OTHER BURIED METAL CATHODICALLY PROTECTED
ZINC PLATES OR RODS INSTALLED ALONG LINE WITH CONNECTION FROM EACH TO LINE
ZINC ANODES
WIRE
PIPE LINE OR OTHER BURIED METAL CATHODICALLY PROTECTED
ZINC PLATES OR RODS CONNECTED IN GROUPS WITH COMMON CONNECTION TO PIPE LINE
GROUND BED – SCRAP METAL OR CARBON RODS
RECTIFIER
A-C SUPPLY
WIRE
PIPE LINE OR OTHER BURIED METAL CATHODICALLY PROTECTED
USE OF BATTERY, RECTIFIER OR GENERATOR TO SUPPLY EXTERNAL SOURCE OF DIRECT CURRENT

Fig. 21 and Fig. 22. Cathodic protection of buried metals



LINE strains, high temperatures and pressures will distort the body of any valve. Only Darling fully revolving double disc parallel seat gate valves have the curved wedge face and transverse bevels that permit the gate to adapt itself to out-of-line positions the valve seats may assume. There's no need to jam or force it; it fits naturally, easily and tightly.

The valve assembly consists of four simple parts—two discs, two wedges. These can easily be removed for inspection or maintenance without taking the valve from the line. When the valve closes, the two wedges force the discs firmly against the valve seats. On opening, the first quarter-turn instantly releases the wedges and frees the discs to be raised with less seating wear.

The discs are fully revolving through 360° and seat themselves in a different position each time the valve is closed. Thus wear on disc and seat is uniform, and life-long, tight closing results.

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Oil's Dilemma—What of the Future?

☆ A discussion of reserves, prices, etc., and what should be done to assure an adequate future supply of oil

*by E. O. Bennett**

Consulting Engineer

NEW and much needed quantities of oil, which normally add to the country's reserves, are being discovered at continually declining rates. Consumption, now at a new all time high, is steadily increasing and will continue to do so for the next year or two unless some major event transpires to retard present war requirements.

Present trends of discovery lend but little encouragement that the increasing volume required can be maintained over any sustained period of time, and there are growing indications that a definite and acute shortage of petroleum products will exist in the very near future.

A brief review of the status of production, consumption, and development is at this time of vital interest to the petroleum industry, and to every citizen of the United States, because this nation is geared to a method of industrial and domestic activity that is entirely dependent upon its petroleum supply. It is not believed that there is an iota of doubt in anyone's mind concerning the value and necessity of petroleum products in the modern mechanized war in which we are embroiled. Recent reductions in rationing of gasoline are now the result of the pending shortage and should make the public conscious of the seriousness of the situation. Failure to improve the crude reserve picture in all probability will cause the retention of gasoline rationing long after the war is ended. Proper public reaction to the necessity of a price increase will do more toward rectifying the rationing now in effect than any other one thing. Public sentiment can do much toward correcting bureaucratic blunders, especially in pre-election periods.

Production is being increased each month. The production at the end of February, 1944, was 66,000 bbl. a day greater than the first of January, 1944. The production for March, 1944, will be greater than that of any single month since the discovery of oil in the United States 85 years ago. It is estimated that the daily production will exceed 4,400,000 bbl. The previous sustained maximum monthly production occurred in December, 1941, and January, 1942, when the daily rate reached a figure of 4,138,000 bbl. a day. The previous all time high was for a short interval at the rate of 4,337,000 bbl. a day during the week of February 7, 1942. Ninety-one percent of the increased production last year came from the state of Texas.

It is estimated the production for March, 1944, will exceed the January production by nearly 2,000,000 bbl. and the June, 1943, production by approximately 15,000,000 bbl.

Production during the first six months of 1943 was the highest during any six months since the discovery of the Drake well in 1859.

Demand Increasing

Present production rates indicate that the requirements for the entire year, 1944, may reach an all time high of approximately 1,650,000,000 bbl. against the previous all time peak in 1941 of 1,400,000,000 bbl. As the greater part of the difference between the totals for 1941 and 1944 have occurred during very recent months with an ever-increasing trend, it is estimated that the production requirements for the rest of 1944 will be an increase over the 1943 volume of from 7 to 10 per cent. A cessation of the rapidly increasing war consumption is the only known factor that could effectively show any appreciable relief from the continuously increasing demand.

The rapid increase in oil production has not been sufficient to permit supply to be kept in balance with demand, and present aboveground stocks are being depleted at an alarming rate. A review of the stock situation in the United States at the end of 1943 shows:

1. That since the end of 1941, gasoline stocks have been reduced by 19,000,000 bbl. This, and not transportation difficulties, is now the main reason for curtailing the value of gasoline rationing coupons, and but little relief may be expected.

2. That residual fuel oil stocks at the close of February, 1944, were 51,000,000 bbl. below the volume available at the high of 1941 and that during the same period, the reduction of distillate fuel oil stocks was approximately 21,000,000 bbl.

3. That crude oil stocks, which increased during the early part of 1943, are now being reduced, despite the fact that production rates have been very substantially increased. Since the high of 1941, crude oil stocks have been decreased by 28,000,000 bbl., and, at this time, are more than 2,000,000 bbl. lower than they were at the corresponding date in 1943.

4. Crude oil stocks are now but little over the minimum of stock aboveground at any time during the last 20 years.

5. The present stock situation very definitely indicates that any sizeable new demand in the immediate future will necessarily have to be provided by increasing current production and refining rates. Recent events on the European, Russian, and Pacific battle zones indicate that much more oil will have to be produced during the next 12 months than during any single year of the entire life of the oil industry.

The significance placed upon the Allied bombing of oil facilities in Ploesti, Roumania, is further indicative of the value placed upon petroleum products for warfare. Everything possible is being done to wreck the enemy's petroleum supply to put him out of the war, whereas but little is being done to increase our own—to assure us of the ability of staying in to a successful conclusion.

The petroleum industry is well aware of its great responsibility to the nation. The fact that it has been permitted to drill less than its normal number of wells for the last two years, because of a shortage of steel, spacing, and other imposed restrictions, coupled with the well known fact that much less new oil per wildcat has been found, sheds grave doubt on its ability to sustain the required volume under present circumstances.

What's to Be Done?

What then may be done to rectify the serious condition the industry now faces?

Under normal conditions the age-

*This is the substance of a talk made before The Petroleum Engineers Club, Dallas, Texas.

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TODAY and TOMORROW
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PETROLEUM'S CONTRIBUTION TO BETTER LIVING

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Synthetic rubber, one of the foremost of these developments, proves to be better than the "natural" for most uses. Shortage of natural rubber plus demands of war, hastened its perfection. A herculean task to be sure, but now synthetic rubber is well on its way to adequate mass production, to serve our everyday needs in countless different ways. Another record of accomplishment by a great industry!

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Where emulsion problems are concerned, Tret-O-lite compounds are recognized by oil producers everywhere as the most effective and economical treating agent for "cut" oil. You'll find Tret-O-lite field engineers solving tough problems in their stride.

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old law of supply and demand would automatically apply in such cases, and the price of oil would be raised to a level where a suitable amount of increased drilling would produce the required oil to maintain proper balance with consumption. It is anticipated that under normal and unrestricted conditions the present heavy inroads on the supply would have been met by the drilling of from two to four times the number of wells that are being currently drilled.

Due to restrictions of material, controlled well spacing, and arbitrarily controlled prices, along with a shortage of manpower, well completions for the first six months of the past year were 22 per cent below those for the corresponding period of 1942. This condition permitted a total of approximately 18,000 wells to be completed for the year of 1943, a new low for the last decade. The total number of wells drilled last year is estimated to be but little over half the number drilled in 1941.

As the number of wildcat wells drilled has been fairly uniform over an extended period, the largest decrease in drilling has then been in proved areas. The result of this has been that the total number of producing wells finished has shown a greater rate of decline than the total number of wells drilled. One of the best means of obtaining additional quantities of oil for immediate use would be to do a great deal more drilling in proved areas.

To increase production rates of existing wells under prevailing conditions means heavier withdrawals. It is a well known fact that the areas and number of wells capable of sustaining higher rates of production are limited. Excessive production rates in many areas would create waste and further aggravate the present serious trend.

The foregoing analysis definitely indicates that immediate action is necessary and that all means of increasing and keeping up such increases are urgent and vital to the domestic, industrial, and military welfare of the nation.

The discovery rate of new reserves can no doubt be appreciably helped by a much greater application of geophysical and geochemical methods of prospecting. Cooperative work among companies offers the possibility of permitting existing equipment and manpower to cover a great deal more new territory, instead of making repeat and overlapping surveys, as occurs under present exploratory practices.

A waiver of some of the old concepts of geology and deeper drilling under many fields in some oil producing areas, not yet tested, also offers substantial possibilities of finding new oil. This procedure is now being advocated by a few of the nation's outstanding geologists. A. Rodger Denison, president of the American Association of Petroleum Geologists, states that there is a section of a mile to a mile and one half thick below any proved zone along the entire Gulf Coast, much of which will be productive.

A price structure for produced oil that will provide a sufficient income for operators to undertake new developments, together with definite assurances of the retention of suitable depletion clauses in federal tax laws, will do more to right present precarious conditions than all other methods combined.

Assurance that a new property may be developed with spacing pattern properly designed for economic return on capital invested and not made to conform to a pattern arbitrarily imposed by governmental agencies, will also assist in stepping up a development program. Evidence of the necessity of waiving certain unsound and not too well planned governmental restrictions is indicated by recent liberalizing of some federal regulations that impeded development. Many cases can be cited in which imposed restrictions forced the drilling of locations that proved dry whereas the locations requested by operators would have produced oil. A geometrical spacing pattern set by a certain well without regard to structural position of a lease has not helped drill the much needed number of new producers. With a given amount of steel for development, operators are generally the best judges of where wells should be located and should be permitted to make such locations. Changes in the PAW with more direct authority in division offices gave some relief and materially speeded up the granting of approvals for new work. This eliminated much of the previous wasted time of executives, consumed by travel between the oil country districts and the nation's capital. Still more could be done in this direction.

Remaining possibilities for increasing daily rates and bolstering the reserve are the intensive application of sound engineering principles and practice to both primary and secondary recovery.

There are numerous oil fields throughout the producing sections of the United States that have been producing for 30 or more years, and many of them are practically depleted from an economic point of view, although the total oil produced from them has, in some cases, been less than 20 per cent of the amount of estimated reserves discovered. Certainly such pools are a challenge to the ingenuity of operators and engineers and offer a source of supply for future recovery.

Primary production control of certain oil pools has, during recent years, permitted the recovery of more than 50 per cent of the oil in place in a very limited period of time, and results obtained indicate that from 65 to 75 per cent of the available recoverable oil may be made available for use, instead of an ultimate recovery of only 15 to 20 per cent.

Minimizing gas waste and the retention, or replacing, of reservoir energy will do much to obtain maximum recovery from any new development.

Cooperation Essential

It is obvious that properly applied production methods must consider a field or pool as a unit and that all owners of leases in the field or pool should work out suitable means of unitized or, at least, cooperative operation for proper procedure and maximum recovery. Many attempted recovery projects have been prevented from being placed in operation because minority interests in a pool refused to participate. Such refusal to participate generally stems from a lack of understanding of modernized technical production methods.

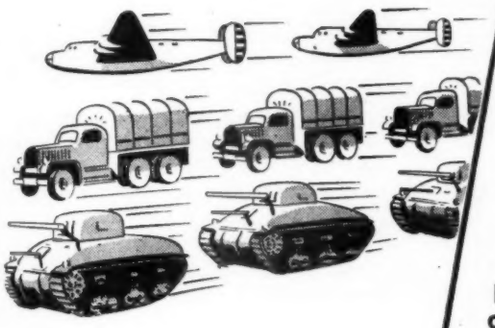
Numerous cooperative enterprises have proved practical and have made increased recoveries possible without complete unitization and it is believed that such operating methods will be more generally practiced in the future.

If the present reserve picture is not greatly helped in the near future, it is believed that both primary and secondary recovery methods will be made mandatory by state oil regulatory bodies. Voluntary undertaking of such activities seems more advisable than obligatory methods. Industry personnel is fully capable of solving its own problems and needs no outside assistance.

Proper control of flush production depends entirely upon the nature of the producing formation, the characteristics of the crude, and the natural sources of motivating energy available. Complete data on each well drilled, including formation characteristics, are essential for suitable analysis and evaluation for the determination of proper production methods. In one case there may be an ample supply of energy available because of an active water drive to displace all recoverable oil and no extraneous energy may be required. In another case the total available energy may be in gas under pressure, in solution and in gas cap, in which case each barrel of oil produced will reduce the total amount of natural reservoir energy available. In both cases careful control of producing rates from wells properly spaced will be required to effect efficient recovery.

In the gas energy or combined gas energy and water drive types of pools

OVER 13,000 WELLS WILL BE EQUIPPED FOR PUMPING IN 1944



The demands of war, according to our government, will require that more than 13,000 wells be equipped for pumping in 1944.

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it is obvious that the return of gas under a suitable pressure maintenance program is not only desirable but necessary for maximum recovery.

The application of secondary recovery to old, partially depleted pools can and will make available large increases in recovery from many pools. Unfortunately the lifting cost per barrel, due to cost of labor and material, is almost equal to the value of such a barrel of oil produced at its arbitrarily fixed static price. Any sizable expenditure of money for surveys and analysis for secondary recovery, and for the installation of mechanical equipment for accomplishing such recovery, will, in all probability, place such a pool in the red column of the ledger and prevent such development from being carried out.

An effective increase in the present oil price, substantially fixed since 1937, during which time the average of all other commodities has advanced more than 20 per cent, would permit a small margin of profit from new secondary recovery operations and would stimulate such installations and augment the present dwindling supply with much oil that otherwise would be lost. Without a price increase, many pools capable of being operated under secondary recovery methods will be abandoned prematurely, placing a still heavier load on the already over-taxed remaining sources of production, even to the possible extent of creating physical waste.

Without a proper price increase for petroleum production little if any remedial work can be done on stripper wells without creating a loss to their owners. As stripper and small well production is a substantial part of the total daily supply, failure to clean out and do necessary remedial work on this type of well will further reduce the amount of production available.

The present reserve picture in the United States is indicative of the ever-increasing cost and hazard in finding a barrel of new oil. A rise in price will, in effect, reduce this hazard and permit a larger amount of wildcat and exploratory drilling, some of which is certain to discover new reserves.

Bonus Plan Unsound

The government's proposal of a bonus in lieu of a price increase is of such insignificant value that it warrants no serious consideration as a workable method of aiding the present reserve picture in the United States. So far as is known, but few have been in favor of such procedure, and they have contributed but little to oil reserves.

To offer taxpayers' money as bonuses for wildcat drilling on the basis recently proposed by the OPA would be to invite unscrupulous and unsound operations whereby those operating under such methods could not lose on dry holes but could profit extensively if production were found. The continuation of exploration on a sound business basis with a suitable price for oil has always properly functioned to balance supply and demand and is the only reliable method of advancing exploration.

The industry needs neither a bonus nor does it desire any but simply a fair return on drilling and production capital invested in order that it may continue in normal operation.

The OPA has recently proposed a new method for getting its bonus system started. This time it is trying to split the strippers away from the rest of the industry and give them a bonus in lieu of a price increase. It is not believed the "divide and conquer" tactics so widely heralded by those under the swastika can or should be applied on the stripper side of the petroleum industry by certain governmental agencies when their efforts to control the industry as a whole failed.

All action against a reasonable and proper price for petroleum seems to be directly in line with the policy of advising the American public that we are about out of oil and that we should spend millions for pipe lines on foreign soil. As one interested in this industry it seems to me that our government should stay out of ownership of oil properties on foreign shores and give the necessary backing to private enterprise and capital.

Under the announced conditions for the Saudi Arabia pipe line it appears that the government could completely dominate control over the oil industry permanently. Its international complications offer a stepping stone to World War III. I, for one, cannot subscribe to the theory that we will soon be out of oil. Freedom of enterprise and removal of the shackles now impeding our industry would soon put supply in balance and keep our wheels of industry turning. The alarm about being out of oil has been sounded too many times during my few years in the industry to believe that we have suddenly approached the end.

How would we ever use a foreign reserve in case of another war? The rubber situation should have taught us a lesson—I wonder if it has?

In a discussion presented before the A.I.M.E. at its 1943 New York meeting, J. E. Pogue of the Department of Petroleum Economics, Chase National Bank, New York, and Frederick G. Conqueron, giving an analysis of 30 oil companies over an 8-year period, concluded with this statement:

"The petroleum industry generated the capital necessary for its maintenance and expansion, thus constituting a self-reliant industry.

"Nearly two-thirds of the capital invested (1934-41) went into the producing branch of the industry, indicating the high cost of replacing and increasing crude oil reserves.

"The flow of funds exhibited cyclic variations, expenditures for capital investments fluctuating with changes in the price of crude oil.

"The consolidated statements here submitted (30 major companies) point to an oil economy functioning soundly and effectively."

What of Prices?

It must also be brought to mind that approximately 75 per cent of all newly discovered oil is found by operators engaged in production only, and their only source of revenue for continued development is from crude oil prices. Profits from refining, transportation, and marketing, therefore, have virtually no effect upon returns to these operators and their ability to conduct further exploration. Normally 50 per cent of the nation's requirements come from new discoveries.

It is a certainty that price would not enter the picture at all if there were now an actual daily shortage of petroleum production for our naval, air, and military operations, and such operations were being hampered because of a shortage. Could we afford to let the war be lost, with resulting consequences, because of a price of oil? The answer is obviously, "No"—even if oil were to cost $5 or $10 a barrel.

Has anyone ever heard any discussions about the price of planes, guns, or ships or other necessities for conducting warfare? Are these regulated and controlled by the OPA? Further, these supplies are fabricated from practically unlimited sources of materials on hand, whereas the future supplies of petroleum are neither unlimited nor on hand, and without an adequate supply of oil all these others would be useless.

Why then must we temporize and let price consideration jeopardize our petroleum supply, which under a war of a long duration could and will put this nation and its allies in an extremely dangerous position by not being able to keep in operation the other tools and engines of war, unhampered by price? What other commodity absolutely necessary for war has actually been restricted because of price? There is none.

In closing, it is of interest to note that the average price of oil under nearly 12 years of bureaucracy has been $1.066 per bbl. and that for the 12 years preceding the present bureaucratic regime, it averaged $1.343 a bbl.

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Determining Well Diameter

☆ Factors influencing the selection of most advantageous hole size in field development

by Lester C. Uren

Professor of Petroleum Engineering, University of California

ONE of the important problems that the engineer engaged in oil field development will be called upon to solve is that of determining the most advantageous well bore and diameter of casing to be employed. The problem has both physical and economic aspects. Larger diameter wells permit more efficient operation and usually can be drilled with greater assurance of satisfactory completion. The casings necessary to support the large diameter hole, however, are much more expensive than casings that may be employed in small diameter wells, and a balance must be sought between these two opposing factors.

The practical and theoretical advantages of the large diameter hole from the standpoint of drilling and production efficiency have long been recognized, but within recent years there has been a notable trend toward "slim hole" drilling, a trend that has been dictated primarily by considerations of economy and fostered by proration restrictions. Some authorities believe that slim hole programs may find wide application; others that they may be advisable only under special circumstances. Perhaps no program will be correct under all conditions that may be prescribed. Each field presents its own peculiar problems that will require varying casing programs. In the current article, it is proposed to review the factors that enter into the problem of determining the most advantageous well bore and casing program.

Influencing Factors

The diameter of the well and the casing in it will influence the cost and efficiency of operations both during the drilling of the well and its subsequent period of production. Small diameter wells can be cased less expensively and this is the principal advantage of the slim hole. Under favorable conditions, the cost of drilling may be less for the small hole and it may be drilled more rapidly. This is not necessarily true however, and if drilling conditions are difficult the larger diameter hole may be drilled less expensively and more rapidly. If intricate equipment must be manipulated in the well during the course of drilling, as in coring, fishing, and certain types of cementing operations, large diameter wells are advantageous.

In the subsequent period of production, the large diameter well is preferable from every point of view. It develops superior productive capacity, greater ultimate recovery, and it produces with lower gas-oil ratio; therefore more efficiently from the energy consumption standpoint. Large diameter casings and well equipment exert less back pressure on the producing formation, permitting flow with lower pressure differential, hence with greater efficiency. A large diameter casing permits use of a larger size of pump, of greater capacity than is possible in a well of small diameter.

When tubing has to be pulled, liners, screens, or gravel-packs placed, "shooting," acidizing, or clean-out operations conducted, the larger diameter well is advantageous. If bottom water or edge-water has to be excluded in a certain producing interval, or if the well has to be deepened to a lower zone, or other work-over operations performed, the larger diameter well permits completing the work with greater certainty and efficiency.

Influence on Drilling

Theoretically, the cost of conducting drilling operations should diminish in some ratio with well diameter. The volume of rock to be pulverized varies as the square of the well diameter. Accordingly, bit and power costs might be expected to vary in this same ratio. For each foot of hole drilled, the weight and volume of drill cuttings to be circulated to the surface increase as the square of the well diameter; hence the volume of fluid circulated and power expended in pump operation increases likewise. The volume of drilling fluid in use increases with well diameter. The amount of clay deposited will depend upon the wall area exposed and this varies directly as the well diameter.

From an analysis of reports assembled in response to a questionnaire circulated under American Petroleum Institute auspices, giving data on some 2300 wells in many fields in different oil producing regions, Alcorn and Teague[2] conclude that the time of drilling varies as the square of the well diameter or directly as the cross-sectional area of the well. Actual time spent in rotating drill pipe is found to vary directly as the diameter of the hole drilled. In some localities, drilling 8¾-in. holes for 5½-in. casing saves 13 per cent in total drilling time and 18 per cent in cost, as compared with the time and cost of drilling 9⅞-in. hole for 7-in. casing, or a reduction in cross-sectional area of 23.6 per cent. The saving in cost of casing the smaller diameter well is substantial. Using 5½-in. casing instead of 7-in. casing, results in a reduction in tonnage of steel of 57 per cent and a cost reduction of 60½ per cent.

Alcorn[1] finds, from inspection of drilling-time studies, that a greater percentage of the time is spent in advancing the hole in small diameter wells than in large diameter wells. Thus, about 65 per cent of total elapsed time is spent in rotating drill pipe when drilling 6⅛-in. hole, whereas only 27 per cent of elapsed time is effectively used in making hole when drilling with a 12¼-in. bit. Alcorn also states that in drilling in the Gulf Coast area of Texas and Louisiana, reduction in well diameter results in reduced drilling hazards. A careful cost analysis indicates that drilling costs, bit costs, mud costs, casing costs, fuel costs, reaming costs, foundation costs, and rig assembly costs are all greatly reduced in drilling slim holes: that in some instances a 7¾-in. exploratory well can be drilled for as little as one-quarter the cost of a 12¼-in. hole.

Field data from different regions are conflicting. It is apparent that small diameter wells are not always less costly than larger diameter wells, and in some instances drilling progress is less rapid than in drilling larger holes. In some areas where difficult drilling conditions are presented, large diameter wells are drilled at lower unit cost than small diameter wells. Gill[4] reports that in the salt dome fields of Texas and Louisiana, where heaving and caving shales and high gas pressures frequently make drilling difficult, trouble is more likely to be experienced in small diameter holes and progress is slower than in

holes of larger diameter. Torrey[4] reports that a study of completion costs of 100 wells in West Texas indicates no appreciable difference between wells finished with 7-in. and 5½-in. casing. Greater speed of completion in the larger size hole practically compensates for reduced cost of casing in the smaller hole. The rate of penetration is greater and wear on tool joints is less when 4½-in. drill pipe is used than with 3½-in. drill pipe. Drilling experience in West Texas has shown that the smallest hole that can economically be drilled with 4½-in. drill pipe is 8⅝ in. in diameter.

Though Gulf Coast operators have been critical of California casing practice, operators in the California fields generally have preferred large diameter wells. Porter[4] reports that in the North Belridge field, a well cased with 7⅝-in. casing required a drilling time of 149 days, whereas a comparable hole equipped with 9-in. casing was drilled in 90 days. He considers that the greater casing cost for the larger diameter hole, aggregating as much as $7500, is more than compensated by the shorter drilling time and superior production characteristics and facility of maintenance of the large diameter well. Whaley[4] compares 2 wells drilled to about the same depth (7500 ft.) in the same field by the same rig and drilling crew. One well was finished with 7-in. casing in 10⅝-in. hole, and the other with 8⅝-in. casing in 12¼-in. hole. The smaller hole was drilled in 55 days with 224 ft. of coring and cost $81,390. The larger hole was drilled in 37 days with 112 ft. of coring and cost $64,543. Phillips[2] states that a study of the cost of drilling 8 wells in the Ventura field of California indicated that the lowest cost per foot was attained with 12¼-in. bits and 5 9/16-in. drill pipe. With smaller pipe it was difficult to keep the holes vertical and much time had to be spent in reaming and whipstocking. In defense of California practice, it may be pointed out that in this area it is usually necessary to cement the casing just above the cap rock, and then complete the well through the reservoir rock with a smaller size liner, whereas in some other areas the same size casing may be carried to the full depth of the well. Also, California fields in many instances produce a heavy viscous oil that requires a larger diameter hole for efficient production.

Influence on Production

The writer[6] and his associates[7,8] have demonstrated that large diameter wells have superior production characteristics in comparison with small diameter wells; that increasing the well diameter through the reservoir rock always increases the well's productive capacity and efficiency. Theory indicates that flow of a single-phase liquid into a well varies directly as the logarithm of the radius of the well bore through the reservoir rock. A two-phase system of oil and gas shows a somewhat greater advantage for the large diameter well. Inspection of this relationship will show that a few inches increase in diameter will make little difference in the rate of production. A 6-in. hole, mechanically reamed to 18 in. or 20 in. will show a production increase of 25 per cent, however, and if enlarged by other means to a diameter of 5 ft., the rate of production will be 1.5 times that of the 6-in. well[6]. Large diameter wells produce with greater efficiency in the use of gas energy, that is, with lower gas-oil ratio and a larger productivity index. They offer less resistance to flow of oil and gas, thus developing a greater drainage influence, and it is reasonable to expect from them a greater ultimate recovery of the drainable oil and recovery of a given quantity of oil in a shorter time.

Large diameter of the well through the reservoir rock does not necessarily require a correspondingly large hole and casing through the overlying formation, for it is possible to make the upper part of the well down to the reservoir rock one of normal size or even a slim hole if conditions make this advantageous; then enlarging the bore of the well through the reservoir rock. Thus the productive efficiency of the large diameter well may be realized with such economy as the small diameter casing may afford. For example, it is possible to drill a 7-in. hole and support it with 5½-in. casing down to the level of the reservoir rock, excavate a cavity of larger diameter through the reservoir rock, and fill this cavity around a perforated 5½-in. liner with gravel to prevent caving and restrain sand. The cavity may be formed by mechanical reaming, by hydraulic force, by acid treatment, or by use of explosives. Gravel may be placed in the cavity by well established methods of gravel packing.

It is often mistaken economy to use too small a well casing. Influenced by initial economy in casing and drilling cost, in adopting a slim hole program the operator may find that the subsequent operation and maintenance of the well is handicapped to such a degree as to occasion ultimate costs or losses far greater than the initial saving. A small diameter casing may require use of tubing and well equipment smaller in size than is necessary for most efficient flowing or pumping of the oil to the surface.

Small diameter tubing may operate as a choke on the well, developing undesirable back pressure on the producing formation in a flowing well and restricting production below what might otherwise be possible. This may be particularly important in certain stages of gas lifting. Small diameter casing may necessitate use of a pump of smaller capacity than the productive potentiality of the well requires. In the Oklahoma City field, for example, wells equipped with large diameter casings were able to produce large quantities of fluid by use of lifting devices impossible to install in small diameter holes[2].

Small casing may seriously hamper well maintenance work and work-over jobs. Withdrawing and reinserting tubing from and into the well, clean-out operations, fishing for parted tubing, working barrels or gas anchors, manipulating packers, gravel packing, etc., are more difficult and tedious when conducted through small diameter casing. Cementing operations to exclude water and deepening a well to produce from a lower zone may require insertion of a still smaller size of casing, and this may not be feasible if the casing in the well is already of minimum efficient size. Generous casing sizes are especially necessary in multi-zone situations where the well is equipped to produce from two or more zones simultaneously.

Alcorn and Teague[2] report that in one field in which well potentials were determined by productivity indices, the average productivity index for wells producing through 6⅝-in. liners and 8⅝-in. casings was 7.0 bbl. per day per lb. drop in pressure, whereas for wells equipped with 4¾-in. liners and 7-in. casing, the average productivity index was 5.9 bbl. per day per lb. drop in pressure. In this field, productivity indices vary from 2.5 to 12 bbl. per lb. drop in pressure. In other fields, where well potentials were determined by flow tests through ¼-in. chokes, Alcorn and Teague report that no appreciable difference was noted in productive capacity as between small and large diameter wells except in a few instances. In producing wells through small chokes, the size of the well bore will have little influence on the production rate.

Weaver[4] gives data on wells producing under comparable conditions in the Santa Fe Springs field of California. One well was equipped with an 8⅝-in. oil string and developed an initial production of 140 bbl. per day, whereas a nearby companion well, producing under similar conditions and equipped with a 4¾-in. liner, had an initial production of 70 bbl. per day. Three and one-half years later the well with the 8⅝-in. oil string was producing at the rate of 80 bbl. per day and the smaller well produced only 32 bbl. per day. Directionally drilled wells in the Huntington Beach field of California, equipped with 6⅝-in. oil strings, produce at least 200 bbl.

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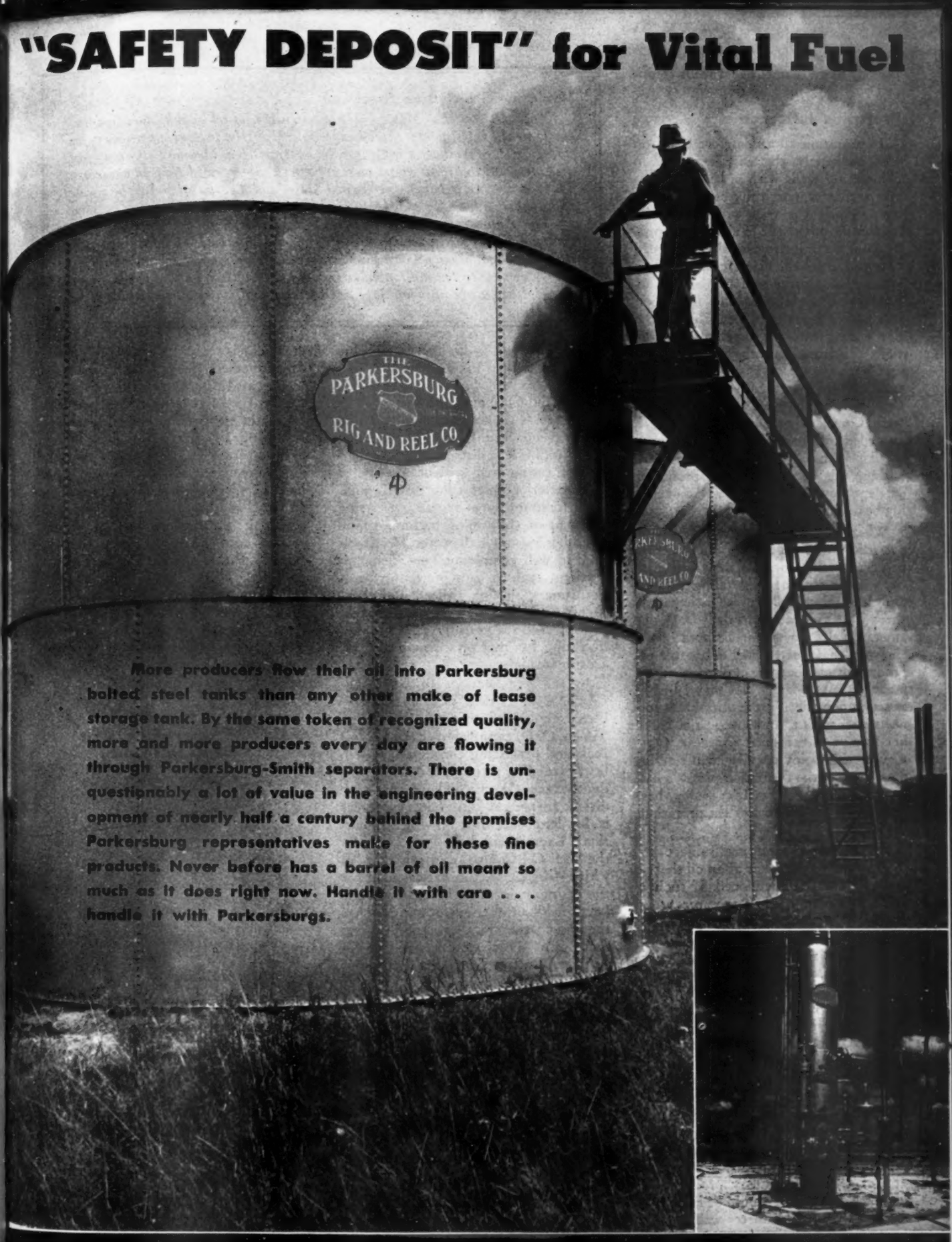

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Proration Influence

If proration allotments are based on well potentials, there is advantage in completing wells with as large a diameter as may economically be feasible for by so doing the well will develop its maximum potential. In open flow production tests it is generally conceded that the larger the diameter of the flow string, the greater will be the rate of production as long as the formation productive capacity exceeds that of the flow string under the pressure conditions existing. Thus the operator who uses large diameter wells is permitted to take a larger share of the producible oil than his neighbor with small diameter wells. On the other hand, if the wells are curtailed by proration restrictions to a small percentage of their potential capacity, this can perhaps be produced efficiently even though the well and casing be of small diameter.

When proration allotments in a high pressure, prolific field are on the basis of acreage or a formula in which well capacity is not the controlling feature and long flowing life is anticipated, there is less incentive to drill large diameter wells, for it may appear that the smaller diameter well is capable of producing all that the proration allotment permits. Many years may be necessary at prescribed production rates for wells to pay out, and low initial costs become of paramount interest. Obviously this point of view will not be tenable after the formation pressure has declined and the well capacity has diminished to a rate below the proration allowance.

Proration practices are subject to change, and in the event of an oil shortage may even be abandoned. If such a situation should develop, operators with small diameter wells might be placed at a serious disadvantage in competition with properties equipped with large diameter wells. In many instances wells have been given proration allowances compelling them to operate at rates below those at which they may produce most efficiently. The pay-out time of wells is thus unduly prolonged and a loss in ultimate recovery results. This would appear to be contrary to public interest and proration practices should be changed to permit use of the most efficient production methods, perhaps by regulating the time rather than the rates at which wells may produce. If this were done, there would be little excuse for the small diameter well.

Practical Limitations

Current drilling practice restricts finishing diameters of wells to a minimum size in which a 4¾-in. liner is placed in a hole at least 6 in. in diameter, to a maximum of 8⅝-in. casing in a 10½-in. hole, which may be reamed through the reservoir rock to as much as 20 in. and gravel packed. Practice varies somewhat in different districts. The smallest size of casing that will permit use of 2-in. exterior-upset tubing with sufficient room for use of a wash-over string in event of the tubing becoming sand bound, is 5½-in. in diameter. Most tools used in well completion and repair operations, such as gun perforators, underreamers, suction bailers, and well-logging devices, are made in sizes that may be used successfully through 5½-in. casing, but may present possible hazards in smaller casing.

In the Ten Sections field of California, wells as deep as 9000 ft. have been completed successfully by setting 5½-in. O. D. casing above the reservoir rock and producing through a 3½-in. liner extending through 250 ft. of productive zone, but no difficult sand conditions are present here and the prospect is for long sustained flowing production[5]. Experiments have been made by the Shell Oil Company in this field, in which 4-in. O. D. tubing was used for the casing string. In the nearby Coles Levee field, another operator finds that the most economical program is one that uses a 7-in. water string and a 5½-in. liner. When wells require deepening, an 8⅝-in. casing is preferred.

In the Gulf Coast region, according to Alcorn[1], a well of normal diameter is one in which a 10¾-in. surface casing is set, below which a 9⅞-in. hole is drilled. Larger holes may provide for 12¼-in. surface pipe, whereas so-called slim holes may start with a surface string as small as 6¼ in. Recently, the trend has been toward a program utilizing an 8⅝-in. surface casing through which a 7¾-in. hole is drilled for 5½-in. casing.

Conclusions

For a given set of conditions, there is an optimum size of well and well casing diameter that will be most advantageous. This is not necessarily the smallest practical working diameter. Small diameter wells are more economically cased than those of larger diameter but they may be more costly to drill. From the production and maintenance standpoint, the large diameter well has every advantage. The problem is largely an economic one and the operator must balance any possible economy in drilling and casing the smaller diameter well against its greater maintenance and operating cost and lower production efficiency. Proration practices have a controlling influence in determining well and casing diameter under some conditions. The economy of small diameter casing and the high production efficiency of the large diameter well may be combined by drilling a small diameter hole down to the cap rock and then reaming to a larger size through the reservoir rock, gravel packing a perforated liner of small size in the enlarged portion of the hole.

Mexican Oil Situation Reviewed

A prediction that Mexico would intensify its oil exploitation and that the United States would extend material aid in the present emergency, was stated by U. S. Ambassador George S. Messersmith in Mexico City to a group of Americans, most of whom were reporters. He revealed that an agreement has been reached between the United States and Mexico whereby the former will provide a loan for purchasing equipment and materials.

The Ambassador pointed out that the Mexican refineries have been in great need of repairs to maintain—and more to increase—productive capacity. Poza Rica, Mexico's best producing field, has shown a decline in output. A loan of nine to ten million dollars would relieve this condition. The money would also be used to increase pipe line facilities and set up a 100-octane plant.

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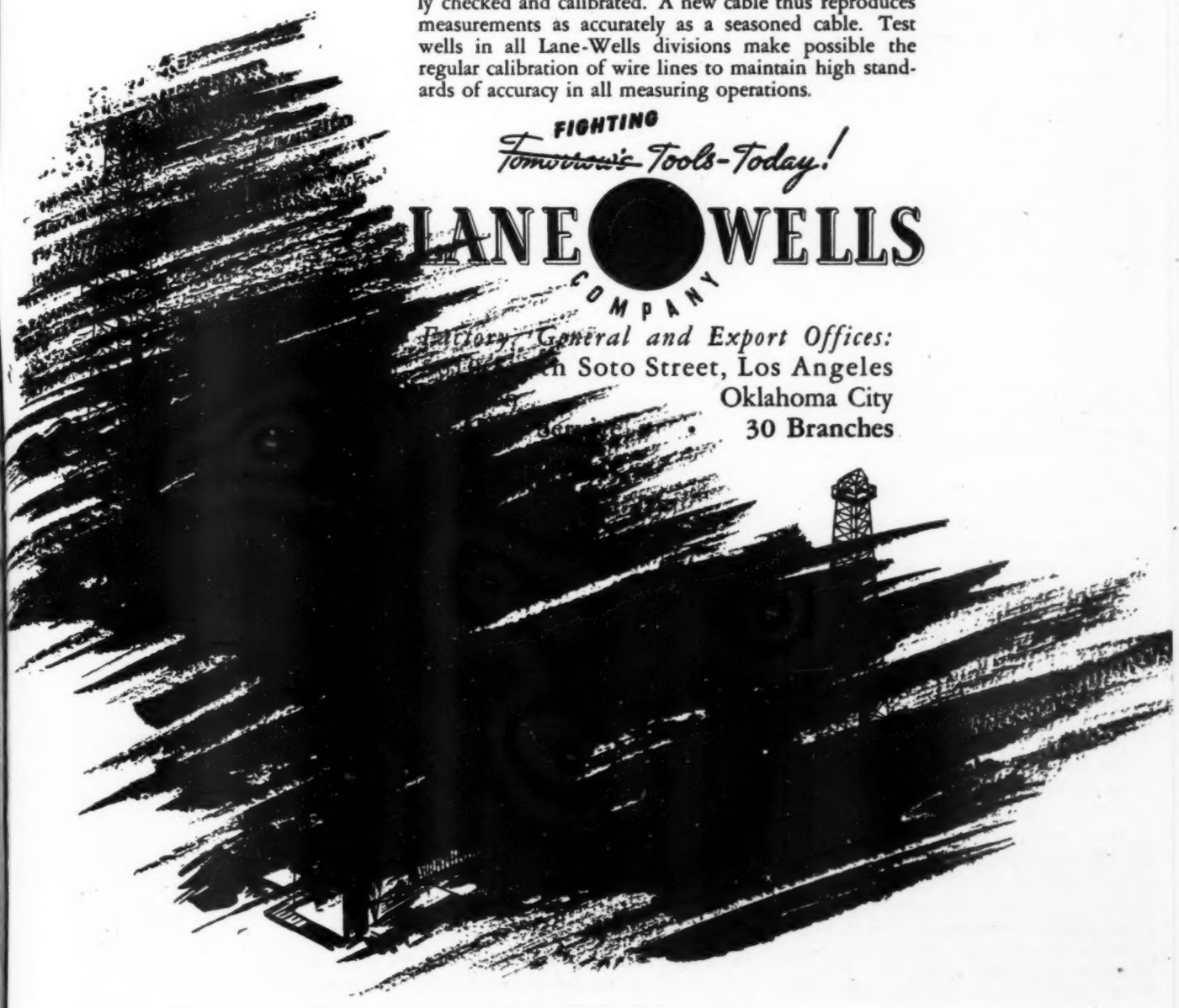

Well Spacing—Its Effect On Recoveries and Profits

PART 3 (Concluded)

by Stuart K. Clark and J. S. Royds
Continental Oil Company
and C. W. Tomlinson
Independent Operator

THE comparisons made thus far have been based on separate fields, or on separate sections of the same field developed on distinctly different spacing patterns.

The data for the Wilcox sand in the Oklahoma City field, Table 4, provide an opportunity for a study of the effects of erratically varying spacing within a productive area. The comparisons have been made by computing spacing and recoveries by quarter sections; grouping them by 4-acre spacing increments as follows: zero to 4 acres, 4 to 8 acres, 8 to 12 acres, and over 12 acres, and averaging the spacing and recovery per acre foot for those groups.

Since some of the conditions affecting this production are unusual, they merit brief discussion.

The production occurs in a truncated sand body on the flank of the anticline. In cross-section normal to the strike of the beds, the pay sand represents a prism, as shown in Fig. 5, bounded by the upper and lower surfaces of the sand, the original water level, and the unconformity at the base of the Pennsylvanian. Total thickness of the sand is about 225 ft.

A, B, and C indicate wells penetrating the pay, respectively, near the up dip edge, in the middle of the productive zone, and near the down dip edge. It is evident that wells near the up dip edge produce from the lower portion of the sand, those near the middle from almost the entire sand body, and those near the down dip edge produce from the upper part of the sand only.

Obviously the wells in the up dip portion of the productive zone are in the best position to benefit from any up dip drainage that may occur.

The areal extent of the productive area is indicated by the map, Fig. 6.

It happens that for the major part of its length, the productive area extends due north-south and is practically spanned by two adjacent rows of quarter sections. If recoveries per acre foot of sand and well spacings are computed by quarter sections and posted on the map, it immediately becomes apparent that of adjoining quarter sections in these two rows, that on the up dip side invariably has the higher recovery regardless of well spacing.

At first glance this would seem to be evidence of up dip drainage on a large scale. There are certain other facts that tend to cast doubt on that conclusion, however. There has been no active water drive in this sand. Many wells near the up dip edge have been depleted and abandoned. The pressure has been reduced to near atmospheric and drainage into the presently producing wells appears to be by simple gravity flow. Furthermore, the phenomenon of higher yield from the up dip quarter sections persists on up through the Mansion area where the pressure had been reduced to about 700 lb. during the years before the development of that area began.

All this suggests that the bottom half of the sand is inherently a better pay zone than the top half.

Plotting the data for the 4-acre increments for the entire sand body and the up dip and down dip quarter sections, respectively, on the well spacing-recovery chart, gives the first three graphs shown in Fig. 7.

The three curves all have one characteristic in common. That is, that they have a steeper slope than that indicated by the overall averages and there is a slight tendency for the slope to increase as well spacing diminishes. In other words, the increase in recovery with closer spacing is greater than would normally be expected.

The range of recoveries even for these 4-acre increments is extremely large, ranging from 325 bbl. per acre foot for a spacing of 13.25 acres per well, to 1315 bbl. per acre foot for a spacing of 3.25 acres per well for the entire Wilcox area. Individual quarter sections, of course, show an even wider range.

The data for the later developed Mansion area, plotted on the well spacing-recovery chart, Fig. 7, indicate an average recovery some 14 per cent lower than that of the entire sand body; but some 22 per cent higher than the average of the down dip quarter sections. The recovery curve approaches the normal expectancy line for the area more closely than any of the other three curves; but even it shows a slightly steeper slope than the normal expectancy line.

The phenomenon of steeper than normal gradients on the well spacing-recovery curves for intra-field groups also is evident in Fig. 8, in which the production from the Texas fault line fields has been broken down by spacing increments within the fields. With the exception of Wortham, the deviations from the normal expectancy line are slight, but all the deviations are toward a steeper gradient rather than a flatter one.

This indicates that for the intra-field spacing groups, the more closely spaced

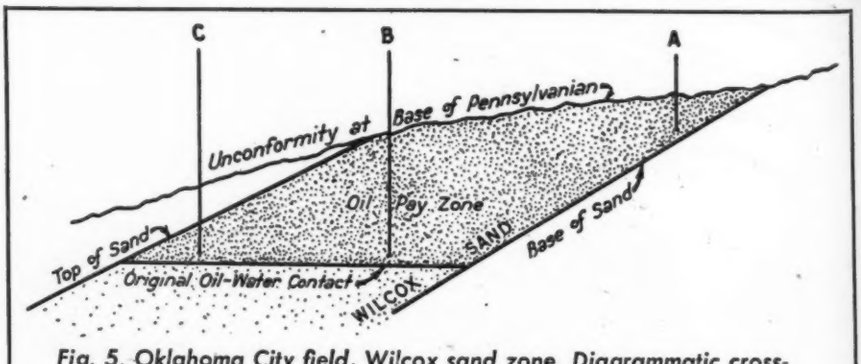

Fig. 5. Oklahoma City field, Wilcox sand zone. Diagrammatic cross-section of oil pay zone normal to the strike of the beds

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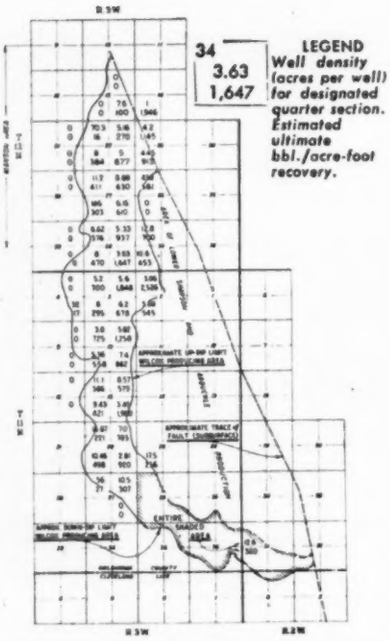


Fig. 6. Oklahoma City field, Wilcox sand zone. Estimated ultimate volumetric yields by quarter sections

wells tend to be benefited, and the more widely spaced ones penalized to a greater degree than would be expected from the inter-field comparisons. In other words, that with varied spacing within a field, the closely spaced wells gain an additional advantage at the expense of the widely spaced ones. The steepening of the gradients of the intra-field curves provides an index of the extent of that effect.

Comparison of the Oklahoma City curves with those of the fault line fields indicates that proration as practiced at Oklahoma City tended to aggravate that effect rather than to mitigate it.

Key Men In Oil Industry Deferred

Key men under 26 years of age in the petroleum industry will be deferred from the draft, it was stated in a release sent out by D. R. Knowlton, director of production, Petroleum Administrator for War. Such men must be endorsed by PAW and the following procedure must be met before deferment will be considered by PAW:

1. Prepare and file 3 copies SS, Form 42-A (special) with the state director of selective service, setting forth in detail the nature of the occupation, qualifications, irreplaceability, etc., of each applicant.
2. Send one additional copy of the same form to the office of the Labor Counselor, PAW, 6640 Interior Building, Washington.
3. Submit to the labor counselor two copies of company certification applying to all men for whom Forms 42-A (special) are submitted. These must be signed by an officer of the company who will assume personal responsibility for the statements contained therein. The certification must state that the individual is employed 48 or more hours a week, and cannot be replaced.
4. If a replacement schedule and summary have been filed with the state headquarters of selective service, a copy of these two documents must also be sent to the labor counselor.

Much additional evidence might be added offering support for the proposition that closer spacing does mean increased recovery; but enough has been presented to establish not only the fact of increased recovery with closer spacing, but that of a definite mathematical relationship between the two. The evidence shows that within the range of ordinary experience this relationship holds, not only for shallow fields and wide open producing conditions, but for comparatively deep production developed with relatively wide spacing and operated under proration with its restrained rates of production.

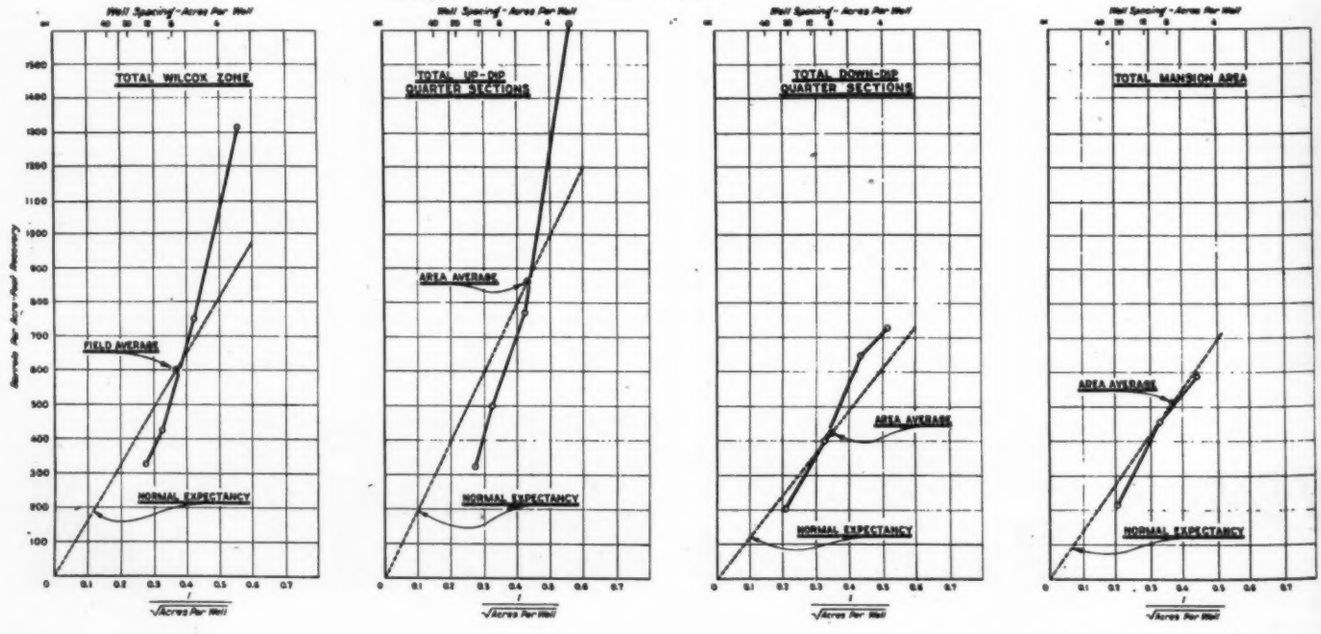
The mere fact that this simple relationship obviously cannot continue to hold throughout the entire range to infinity in the direction of closer spacing, does not invalidate it for use within practical limits. In this respect, it is analogous to the laws of gases, which are useful tools within the critical temperatures and pressures, which limit their application.

That mathematical relationship is presumably an index of the unavoidable losses inherent in any system of oil field development in which recovery of the oil depends upon forcing it to a series of isolated points within the reservoir; i.e., the drill holes penetrating the sand, in somewhat the same way as entropy is a measure of the inescapable loss in any heat power engine. It seems obvious that some loss is inevitable in the oil well method of exploitation as compared with actual mining of the sand and washing it free of oil, or as compared with pumping oil through a pipe line.

Probably a substantial part of the increased loss accompanying wider spacing may be attributed to the fortuitous location of the drill holes in the reservoir with respect to the areas of exceptionally high porosity and permeability in sandstones or the naturally developed drainage channels in limestones or dolomites. All reservoir rocks vary laterally in some degree. As a consequence, individual wells vary greatly in their productive capacities. One well will often yield as much as half a dozen of its neighbors. At the other extreme are the dry holes that are occasionally completed in the hearts of fields due solely to local impermeable areas in the producing horizon.

The odds against tapping all the local

Fig. 7. Oklahoma City field, Wilcox sand zone. Estimated ultimate recoveries calculated by quarter sections and grouped in spacing intervals of 4 acres per well



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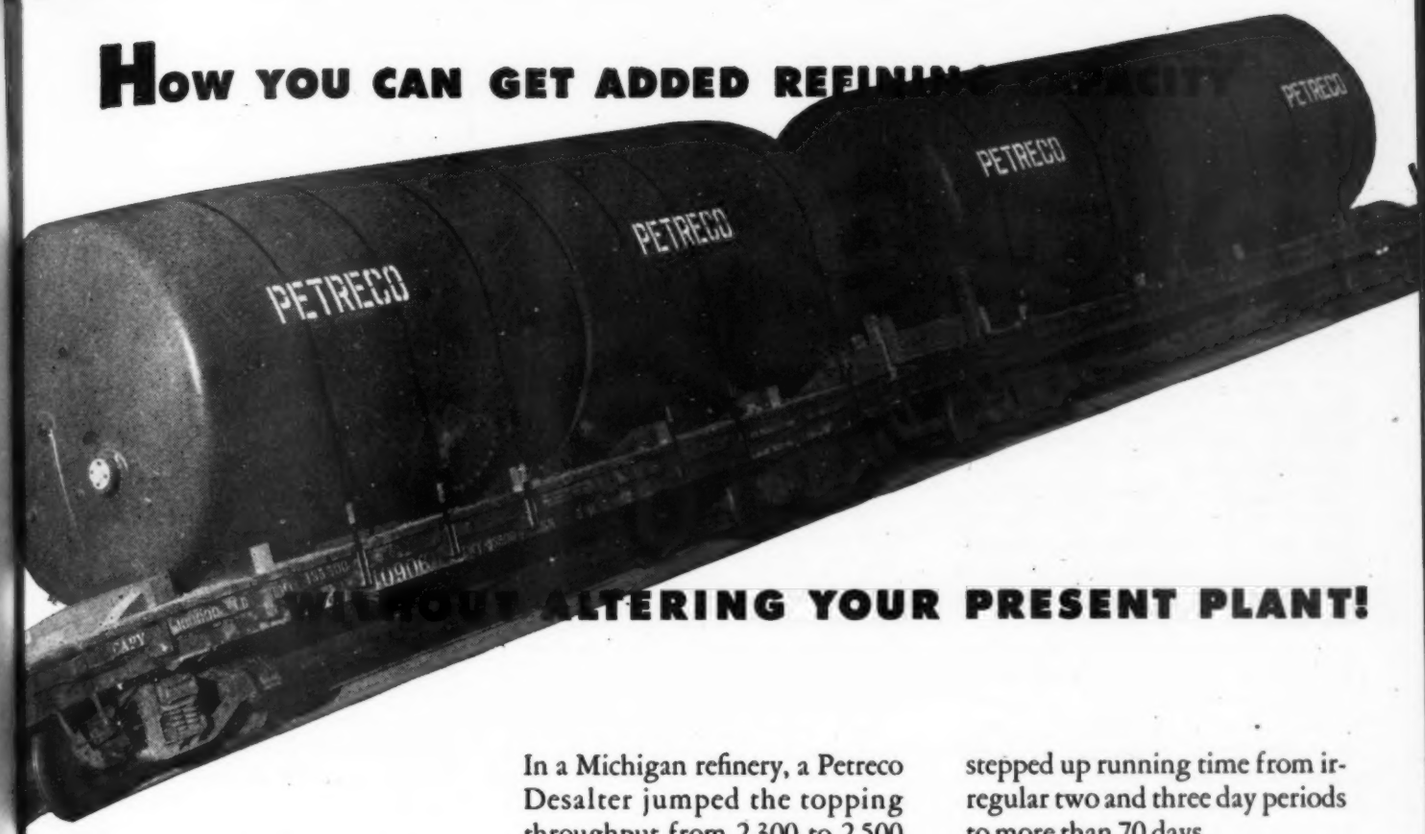

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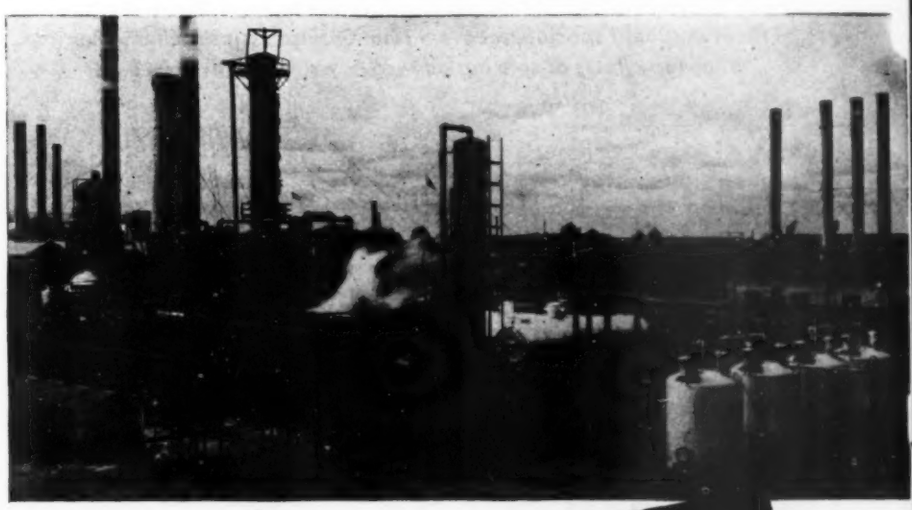

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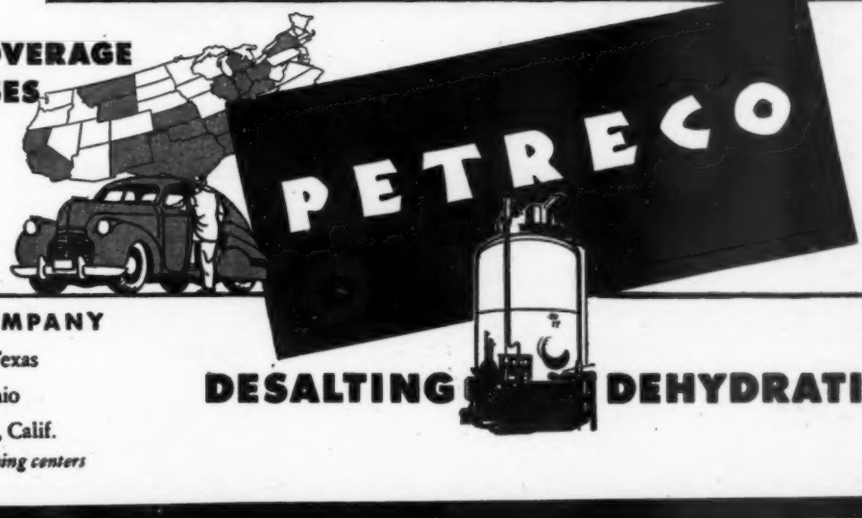

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"sweet spots" naturally increase as well spacing widens, and no doubt that fact is reflected in the lower average recoveries per acre foot indicated for more widely spaced wells.

It is not necessary to undertake an exhaustive analysis of the problem of radial drainage to visualize other reasons for such losses. Pressure gradients along any radius through a producing well are steep in the immediate vicinity of the hole and flatten out rapidly with increased distance from it. The pressure divides between wells may be visualized as almost imperceptible reversals rather than sharp ridges.

In the case of exclusively solution gas drive fields for instance, it is inconceivable that the oil along these pressure divides could ever be moved to the wells by the energy originally available in the reservoir.

In the case of water drive fields where water from outside the original oil accumulation is available for replacement of fluid removed and provides a source of replenishment of energy, we should expect a greater recovery than in the gas drive field. Pressure divides between wells will still exist, however, and movement of the water toward the wells will tend to be along the steepest pressure gradient and accordingly the shortest line.

Fig. 9 illustrates a situation in which wells 1, 2, 3, and 4 are equally spaced and are equidistant from the original oil-water contact line A-B at the top of the producing sand. Bearing in mind that oil in the majority of natural reservoirs does not have the same freedom of movement as in an open vessel, but must be moved through openings of capillary size at an appreciable expenditure of energy, it seems evident that after a lapse of time the oil-water contact would tend to assume the position indicated by the broken line C-D.

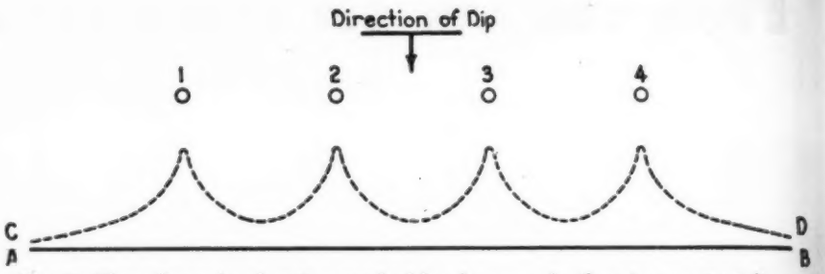


Fig. 9. Plan diagram showing probable change of oil-water contact line at the top of a producing sand in a water drive field as the oil is produced through wells 1, 2, 3, and 4

Such lobes in the advancing water front would tend to become further accentuated as production continues, with the result that presumably some oil along the pressure divides would eventually be by-passed entirely even in an ideal sand with uniform porosity and permeability throughout. In actual practice, of course, both lateral and vertical variations in the reservoir rock generally prevent the development of anything approaching a uniform water front moving through the sand, which, of course, tends to aggravate the matter of by-passing.

It also seems evident that the lobes pictured in Fig. 9 would tend to be the more strongly developed, the greater the distance between wells, although it would require infinitely close spacing, i.e., trench rather than well exploitation, and consequent linear rather than radial drainage to eliminate them entirely.

Granting the hypothesis that the indicated mathematical relationship between well spacing and recoveries is an index of the inherent inefficiency of the well system of oil field development, there is no justification for the assumption that that relationship can be destroyed by the adoption of different production practices.

Certainly restraint of the rate of production as practiced in the Lucien field did not affect it materially.

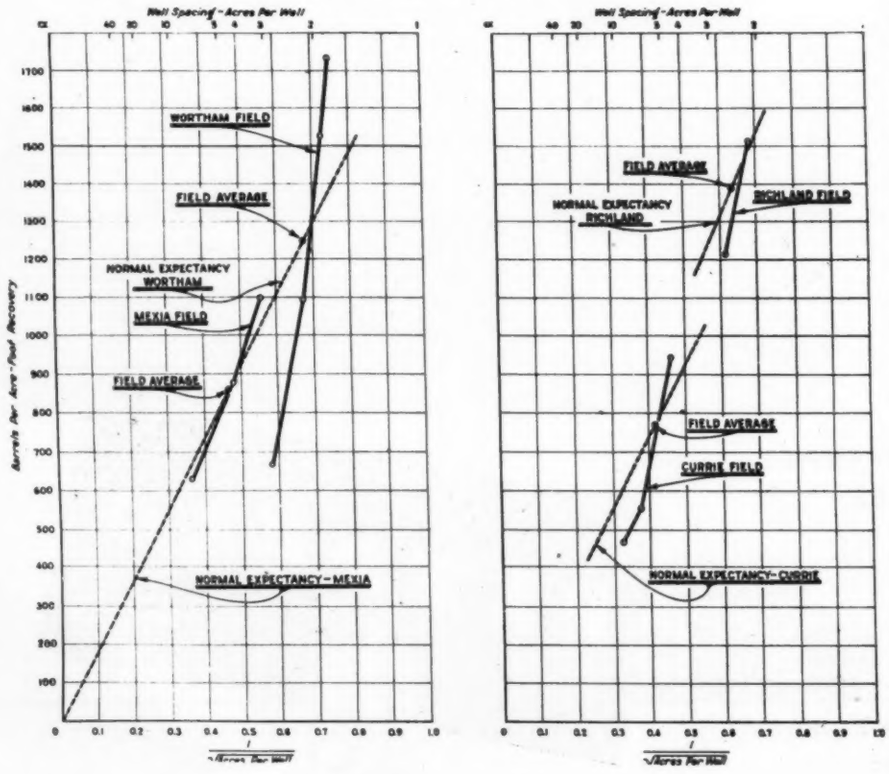
Nor is there any reason to think that repressuring by the cycling of casing-head gas, the introduction of gas from extraneous sources, or the use of an artificial water drive can wholly eliminate the effect of well spacing. They can effect increases in recovery it is true, but they all involve the creation of steeper pressure gradients along straight lines from the input wells to the nearest producers than exist along other radii from those producers, with a consequent tendency to by-pass oil along the intervening pressure divides.

Within certain practical limits there is no reason to assume that the adoption of a more efficient production method would not effect an increase in recovery regardless of the existing well spacing.

The total volume of oil originally present in the reservoir constitutes the final limit, which all efforts toward increased recovery can only hope to approach. It is highly desirable that the general order of magnitude of the figures as they apply to the unit of reservoir volume be kept in mind. An acre foot of sand occupies a space approximately equivalent to 7750 bbl. of 42 gal. each.

An acre foot of sand with a porosity of 25 per cent therefore contains void space amounting to 1937 bbl. If 15 per

Fig. 8. Intrafield spacing, recovery relationships Texas fault line fields, showing effects of spacing on recovery within individual fields



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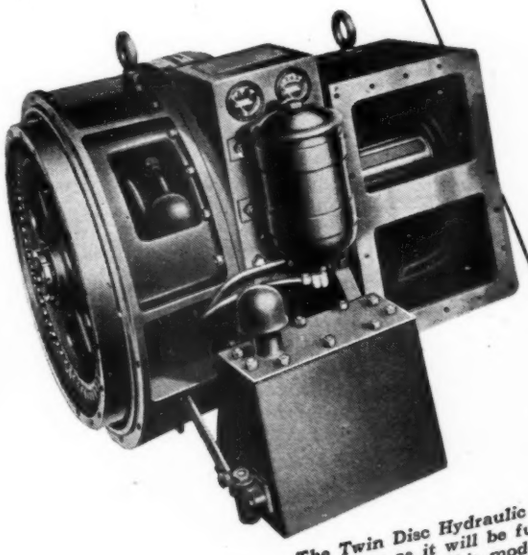


The Twin Disc Hydraulic Torque Converter as it will be furnished after the war. This model incorporates the same basic principles as the Converter which drives the M-4 Military Tractor.

cent of that space is occupied by connate water, that available for oil is reduced to 1560 bbl.; and if 15 per cent of the volume of the oil represents dissolved gas, the space occupied by tank battery oil shrinks to 1325 bbl. These figures convey a fair idea of the outside limitations on the productive possibilities of a sand with 25 per cent porosity.

As these limits are approached, it is obvious that further appreciable increases cannot be expected either from closer spacing or refinements in production practice.

A close approach to these limits as a result of close spacing is indicated by the Wortham field recovery of 1245 bbl. per acre foot with a spacing of 2.2 acres per well under the wide open flow conditions that have frequently been branded as inefficient and wasteful. It should be noted that the increased recovery attributable to closer spacing is a very substantial figure. Thus Wortham's 1245 bbl. represent an increase of 475 bbl. or 62 per cent more than the 770 bbl. recovery at Currie. The total indicated gain at Wortham amounts to 8,950,000 bbl.

It should be obvious that any improvement in production practice which can demonstrate a recovery equal to that obtained at Wortham from a sand of equal porosity with a decidedly wider spacing, will have eliminated the need for consideration of any closer spacing than was used in that instance. Certainly unless they do result in recovery comparable to that obtained at Wortham, porosity and other factors considered, no production practices applied to widely spaced wells can be said to have eliminated all need for considering the possibilities of obtaining additional oil by means of closer spacing.

All the foregoing discussion has considered only the effects of spacing within the field. If all fields were limitless in extent, no other factor would need be considered, but oil fields are limited in area, and authorities agree that the average size of fields discovered in the United States during recent years has shown a persistent decline. This decline in field size, coupled with arbitrarily imposed wide spacing patterns that now generally prohibit drilling more than one well to 40 acres, has created additional problems that cannot be ignored in any study of the economic effects of well spacing.

One of these is the problem of obtaining locations actually capable of draining structurally controlled accumulations in fields of small areal extent under arbitrary wide spacing patterns. This includes narrow accumulations against faults, where adequate development becomes a veritable nightmare under existing spacing regulations, and all sharply folded anticlines and domes of small extent.

The nature of the problem may be indicated by carrying it to an extreme for illustrative purposes. If the regulations specified that only one well could be drilled in each section of land, and that it must be located at the center of the section, it is evident that many small fields could not be exploited at all because of the impossibility of finding any location on the regular pattern that would fall within their limits.

The same difficulty in principle arises when an operator attempts to select locations on a rigid, uniform 40-acre spacing pattern to exploit a given pay zone in a narrow fault-trapped field.

The Wilcox sand production in the Crescent field, Oklahoma, provides a perfect illustration of the problem as it applies to a narrow sharply folded and faulted anticline. It is a particularly

Fig. 10. Crescent field, Oklahoma. Cross-section "A-A", showing limited extent of "Big Pay Zone" in the Second Wilcox sand

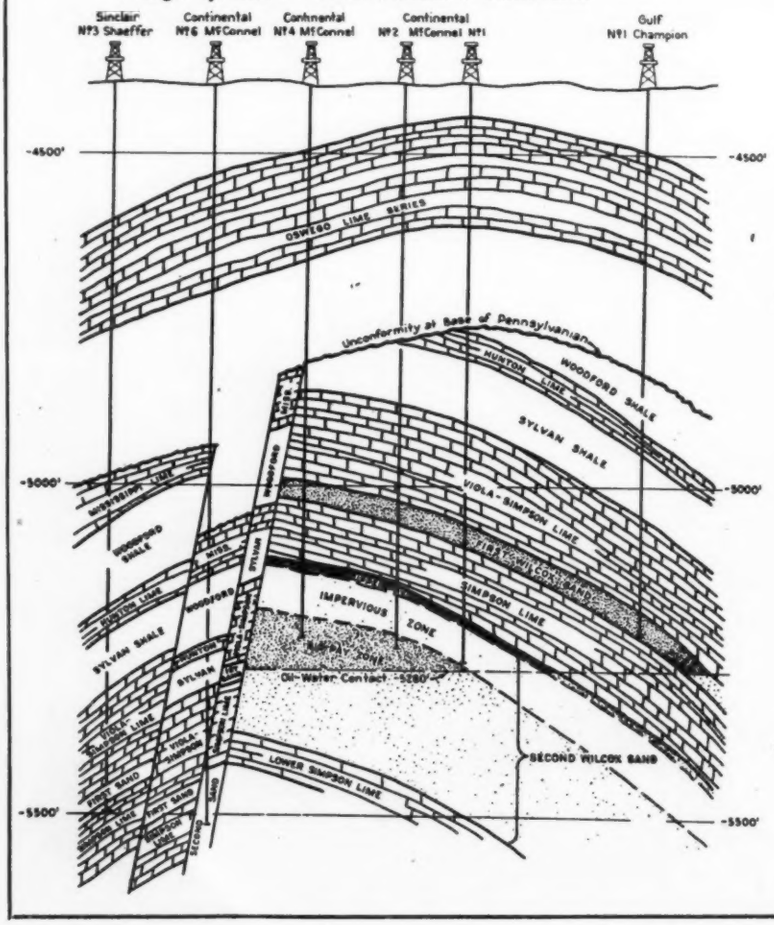
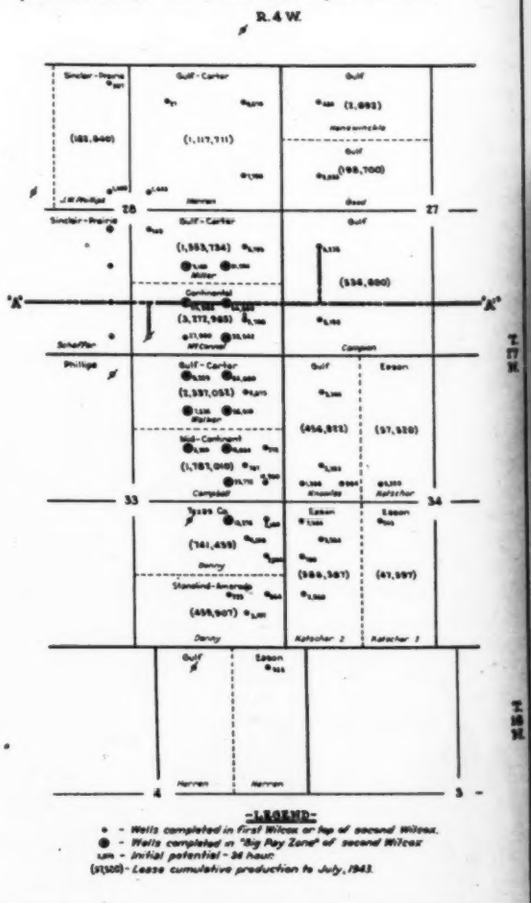


Fig. 11. Crescent field, showing wells that penetrated "Big Pay Zone" in second Wilcox horizon; initial production, and cumulative production



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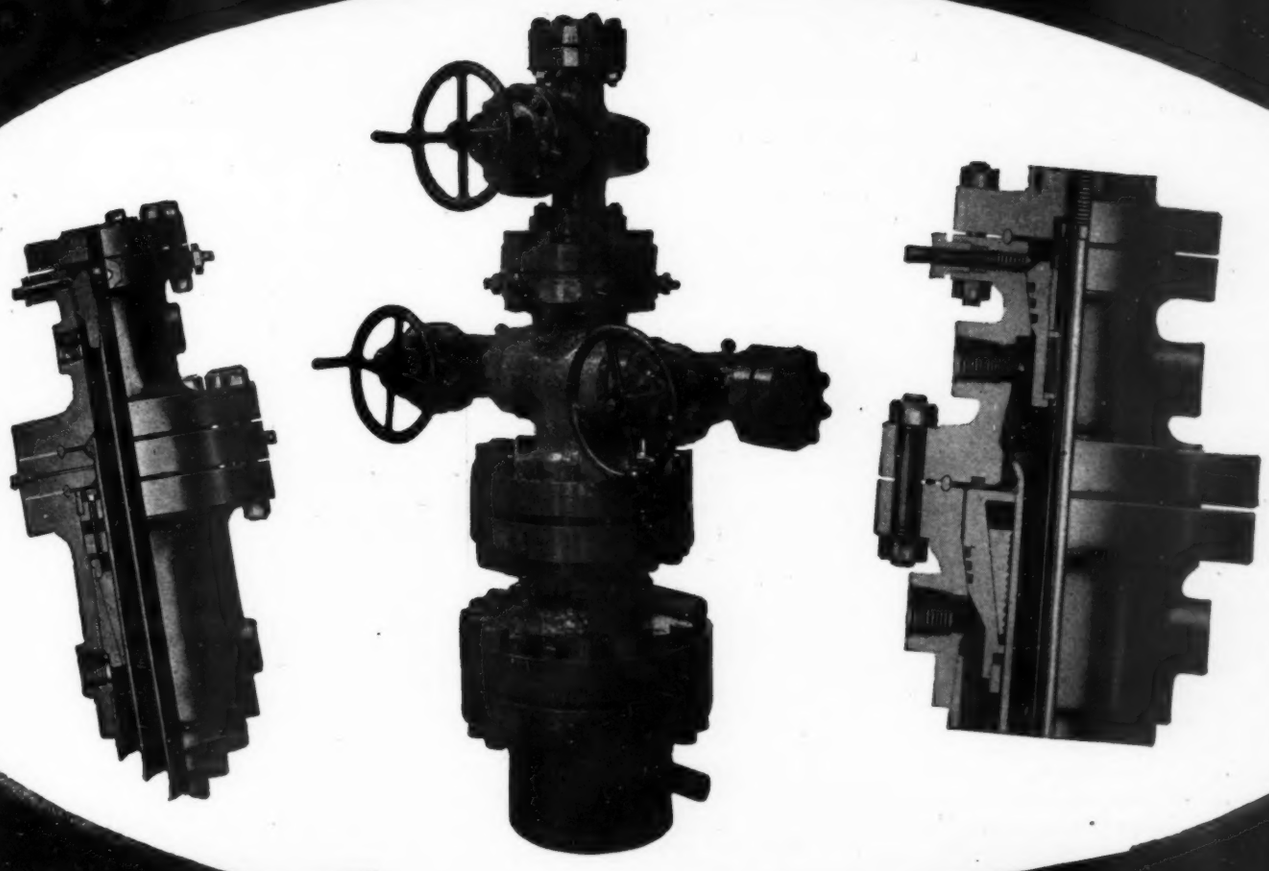

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pertinent example because the field development was initiated on a 40-acre spacing, but was subsequently switched to a 10-acre pattern as a result of vigorous protests by some of the operators affected.

It happens that the axis of the structure in the Ordovician rocks runs practically due north-south. Consequently, the east-west cross-section, Fig. 10, indicates the relative positions of the north-south rows of 10-acre and 40-acre locations, respectively, that are closest to that axis. The Second Wilcox sand in this field included a tightly cemented, practically impermeable zone below its upper pay zone. Beneath that tightly cemented zone was a lower pay of exceptional caliber from which initial productions ranging up to 64,000 bbl. per day were obtained.

Only the two rows of 10-acre locations along the crest of the structure produced from the prolific lower pay zone. Those producers are indicated and the initial productions of both the First and Second Wilcox sand wells are shown in Fig. 11.

Production from the leases shown has amounted to 13,338,996 bbl. Although segregated production figures are not available, it seems probable that more than half of the total was obtained from the extremely productive lower pay zone, which would never have been tapped at all if the original 40-acre spacing had been adhered to throughout the development.

The particular difficulty of selecting structurally satisfactory locations on a rigid spacing pattern could be mitigated materially without increasing average well density by a simple ruling, that equal density of development does substantial justice as between adjoining operators and royalty owners and consequently that having established the density by fixing the area to be included in a drilling unit, all further restrictions as to where within that unit the well may be drilled will be eliminated. In fact, such a ruling seems essential as a matter of justice both to operators and to royalty owners.

Another problem created by wide spacing lies in the increased ratio of dry holes to producers drilled in developing a given field. As field area diminishes, that ratio tends to increase, well spacing being constant. The extreme case is that of the one well pool with dry holes offsetting it in each of the four cardinal directions. That situation will naturally be reached sooner with a wide spacing pattern than with a close one as field size declines. The same tendency exists in fields of greater extent. So with decreasing field size and increasingly wider well spacing, a large increase is inevitable in the percentage of total footage drilled that goes into the unproductive holes required to determine the limits of a field.

If one well will not effect the same recovery as a number of wells will from a reservoir, regardless of size, then there is a definite loss involved in this increasing percentage of dry hole footage, which serves to offset or cancel out a part of the apparent saving in development cost credited to wider spacing.

Discussions of the effect of well spacing on profits in recent years have for the most part assumed that recovery would be independent of spacing and consequently that the reduction in development cost effected by widening the spacing is all net saving. If this were literally true, there would be no justification for drilling more than one well in the smaller fields.

There has also been a tendency to focus attention upon development costs (in terms of cost per producing well only) and profits per dollar invested (with the same restriction as to investment items). Such a presentation of the subject gives a very seriously distorted picture. It is heavily "loaded" to favor wide spacing since development cost, figured on a flat price per well, increases in direct ratio to the number of wells drilled; whereas the recovery of oil increases only in proportion to the square root of well density.

There is little excuse for such distortion of the facts, since the actual possibilities for reductions in costs through wider spacing should be sufficient argument for the adoption of as wide a spacing as is practicable and economically sound.

It is the further purpose of this discussion to indicate the factors that must be taken into consideration to arrive at any fair appraisal of what is practicable and economically sound.

Those factors are:

1. The recovery per acre obtainable;
2. The price of the oil;
3. The cost of finding and acquiring each productive acre (including the cost of condemned acreage and exploratory dry holes);
4. The cost of development per productive acre (including probable cost of dry holes drilled to define field);
5. The probable cost of producing the oil;
6. The practicability (as a physical possibility) of adequately exploiting a particular accumulation with a given spacing pattern.

Total recovery per acre for a known thickness of pay may be estimated with the aid of the recovery-well spacing chart, using a point established by known recovery for one spacing from a closely comparable reservoir operated under similar conditions, and the zero point of the chart to determine a line along which unit recoveries for other spacings may be read. Multiplying those figures by the pay thickness will give the total recovery figures.

The price of oil used would normally be the prevailing field price. It may at times, however, be desirable to extend the investigation to include the effects of a range of prices; and under conditions of extreme depression or boom, it would be advisable to use a price representing the reasonable expectancy over a long period of years.

The cost of finding and acquiring each productive acre has generally been ignored in studies of the economics of well spacing; but to do so is to assume that an unlimited number of oil fields is available upon which an operator may move at will and begin exploitation with no prior expense.

Nothing could be further from the truth. The proved but undeveloped leases available to any operator for exploitation are definitely limited in number. On the average they represent a large investment in the form of scouting, land, geological, and geophysical expense, lease bonuses and rentals and unsuccessful wildcat tests. Certainly, if an individual company is to remain in business and the industry as a whole is

TABLE 5

Comparison of effects of various well spacings

Item	Well spacing pattern—acres per well			
	40	20	10	5
Number acres in production area	1,600	1,600	1,600	1,600
Sand thickness (avg.)	35	35	35	35
Recoveries:				
Per acre ft.	175	250	350	500
Per acre	6,125	8,750	12,250	17,500
Total	9,800,000	14,000,000	19,600,000	28,000,000
Net oil to ¼ w.i.	8,575,000	12,250,000	17,150,000	24,500,000
Price (net after production tax)	1.20	1.20	1.20	1.20
Gross w.i. revenue	$10,290,000	$14,700,000	$20,580,000	$29,400,000
Costs: Finding and acquisition at $1,000 per acre	1,600,000	1,600,000	1,600,000	1,600,000
Development (number wells)	40	80	160	320
Wells at $30,000 each	$ 1,200,000	$ 2,400,000	$ 4,800,000	$ 9,600,000
Dry holes—6 at $17,500	105,000	105,000	105,000	105,000
Other facilities at $300 per acre	480,000	480,000	480,000	480,000
Total development	$ 1,785,000	$ 2,985,000	$ 5,385,000	$10,185,000
Lifting costs per bbl.	0.25	0.188	0.147	0.118
Total	2,450,000	2,632,000	2,881,000	3,304,000
Total costs	5,835,000	7,217,000	9,866,000	15,089,000
Net profit	4,455,000	7,483,000	10,714,000	14,311,000
Cost per net bbl.	0.68	0.589	0.575	0.615
Profit per dollar of costs	0.763	1.03	1.08	0.948

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to remain solvent, all these costs must be returned out of the operating profits from the productive leases.

Furthermore these items in total represent a flat charge per acre, *which accordingly becomes an increasing charge per well as spacing is widened.* To illustrate with the simplest possible case, if an individual with no other investment in the oil industry were to buy a proved but undeveloped lease on 160 acres at a cost of $2000 per acre, that bonus cost would represent his entire "finding and acquisition cost." The entire amount obviously must be returned out of net revenue from operations on the lease before any profit can be realized.

The amounts of the bonus cost chargeable to individual wells under various spacings is indicated in the following tabulation:

Total finding and acquisition cost per acre	*Well spacing, acres per well*	*Finding and acquisition cost chargeable to each well*
$2000	10	$20,000
$2000	20	$40,000
$2000	40	$80,000

Each operator can determine his unit finding and acquisition cost by totaling all land, scouting, and exploration costs, including exploratory dry holes, over a period of years and dividing that total by the number of acres brought into production during the same period. For the industry as a whole, that cost is probably in excess of $1000 per acre.

The cost of developing a given piece of acreage to a given horizon with a given well density can be estimated with a high degree of accuracy. The only comment concerning it that seems necessary is that for a fair comparison for different well densities the items of cost should be broken down into two classes: the cost of the wells themselves, and the cost of the other facilities necessary for the operations. Only the cost of the wells increases in direct proportion to the number drilled. Other development costs such as tankage, lease houses, warehouses, water systems, etc., are largely independent of the well spacing adopted.

In figuring comparative development costs per acre for various well spacings, the cost of dry holes required to define the limits of production should properly be included.

This may be treated as a constant number of wells for a given field, although in actual practice the number will tend to increase with wider spacing.

Direct lease expense or lifting cost, in contrast to well costs, does not increase in proportion to the number of wells drilled. One-well leases are notoriously high cost operations. The organization required to operate a field developed on 10-acre spacing is only slightly larger than that required if the spacing is 20 acres per well. Unit lifting costs consequently tend to decline as well density increases; or the additional oil recovered by closer spacing can be lifted at a fraction of the cost per barrel chargeable against that portion of the oil recoverable through the wider spacing pattern.

Determining the practicability, from the standpoint of physical possibilities, of a given spacing pattern for the exploitation of a given field, simply involves an examination of those possibilities in the light of the physical conditions controlling the accumulation. The difficulties involved in attempting to develop small sharply folded structures or narrow multiple sand accumulations against inclined fault planes on wide spacing patterns have previously been discussed.

Table 5 presents an analysis of the effects of various well spacings in terms of overall costs and profits and in costs per net barrel of oil recovered and profits per dollar of total costs, in a hypothetical case based on assumptions as to field size, sand thickness, and productivity, well costs, etc., which are well within the range of ordinary experience.

This analysis takes all the foregoing factors into consideration. It is assumed that the dimensions of the productive area are such that it can be exploited by any of the spacings indicated. Consequently, it may be regarded as a fair comparison of the effects of different spacings.

The resulting figures may be rather startling to those who have become accustomed to thinking that wider spacing invariably means a great saving, with consequently reduced unit costs and increased profits. For the conditions stated it is evident that, from the strictly cold-blooded standpoint of costs per net barrel of oil recovered and profits per dollar expended, the 10-acre spacing has the advantage over either the 20- or 40-acre spacings; and it is only when the density of a well to 5 acres is reached that the additional oil recovered involves the penalties of higher unit costs and decreased profits per dollar of costs.

It should be emphasized that the barrel of oil in lease storage awaiting acceptance by the pipe line is the oil producers' finished product. Every item of cost incident to putting it there must be considered to obtain a fair comparison of the economic effect of different well spacings. The omission or misapplication of any of those figures can only produce distorted results.

Its pro rata share of the total of those costs represents the operators' investment in that barrel of oil; and it is the profit per dollar of that investment that is significant rather than the apparent profit from lease operations only expressed in terms of an "investment" figure covering lease investment only and computed on a flat well cost basis.

Conclusions

Summarizing, the evidence presented makes certain conclusions inescapable. They are:

1. That well spacing does affect the recovery of oil from a reservoir; that increased well density results in increased recovery; and that within practical limits there is a definite mathematical relationship between the well spacing and the recovery.

2. That arbitrary wide spacing regulations impose definite handicaps on the adequate exploitation of small accumulations on sharp folds or against faults, and tend to increase the ratio of dry holes to producers in all cases.

3. That even from the standpoint of cost per barrel of crude recovered and of profit per dollar expended, it is not invariably true that the wider of two spacings is the more economical. For a given set of conditions there is a certain spacing that is the most economical one, and either a closer or a wider spacing will involve higher unit costs and lower unit profits.

Certain other conclusions may legitimately be drawn from these basic ones.

Although nothing herein is to be construed as an argument against the adoption of improved production practices in the attempt to obtain greater recoveries at lower costs, it would appear that a simple and highly effective method is being neglected when the possibilities of close spacing are ignored.

Since more wells mean increased recovery, there is a strong incentive to work toward lower development costs by utilizing every expedient to reduce the cost of the individual well rather than by widening the spacing.

When wide spacing is temporarily adopted either because of material shortages or lack of information regarding the reservoir, it is highly desirable that a pattern be selected that will permit increasing the density by drilling intervening wells later.

With the existing urgency for an augmented crude supply, it would seem logical to resort to the drilling of additional wells in fields now having wide spacing that are favorable to closer spacing, especially since such drilling would add potential production and reserves, with an absolute minimum of equipment as contrasted with the material requirements for exploiting new fields.

Finally, since optimum well density varies with crude prices, it would appear to be in the public interest for crude oil prices to be increased to levels that would encourage relatively close well spacing so long as the present downward trend of discoveries in relation to production continues.

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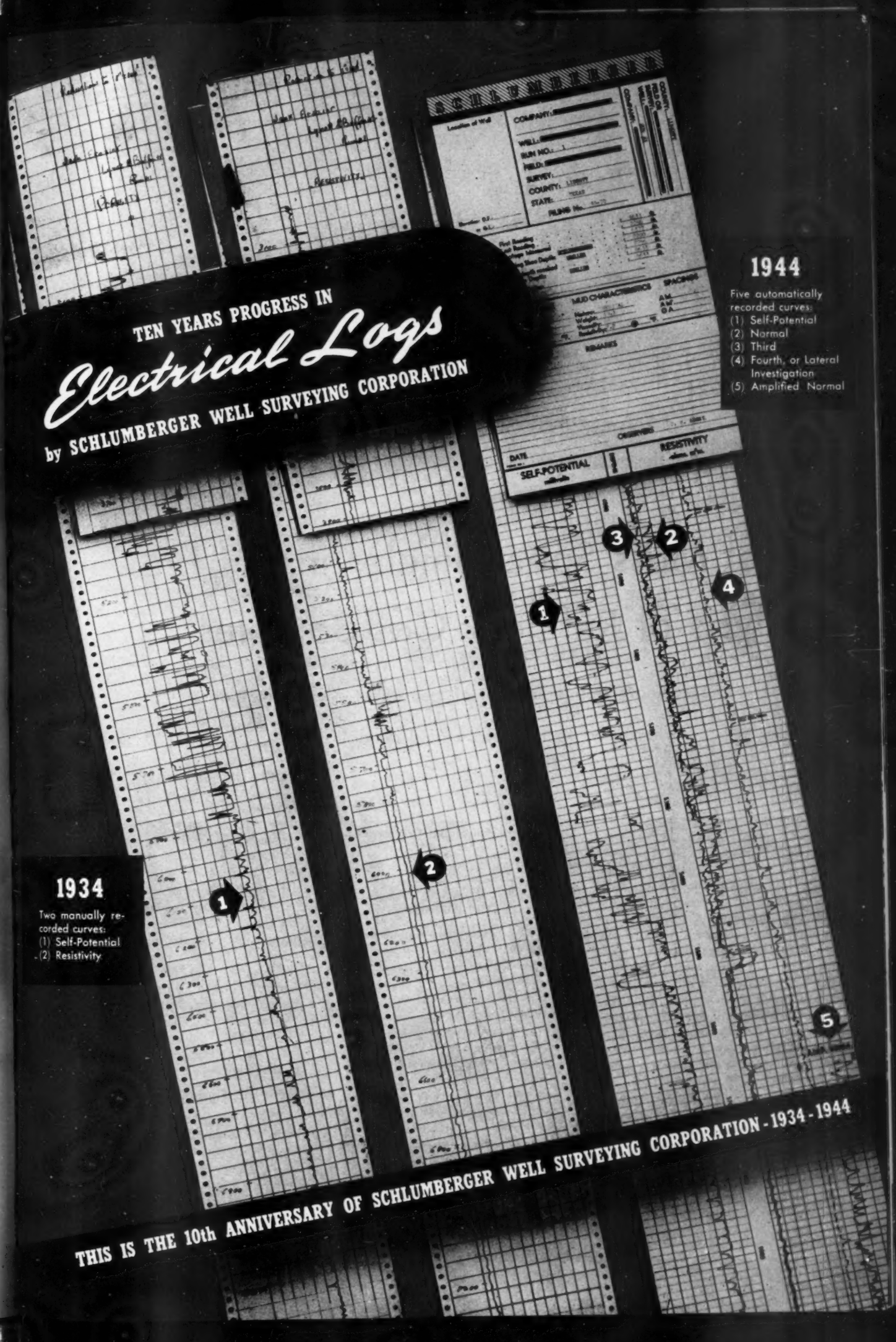
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(3) Third
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(5) Amplified Normal
1934
Two manually recorded curves:
(1) Self-Potential
(2) Resistivity
SELF-POTENTIAL
RESISTIVITY
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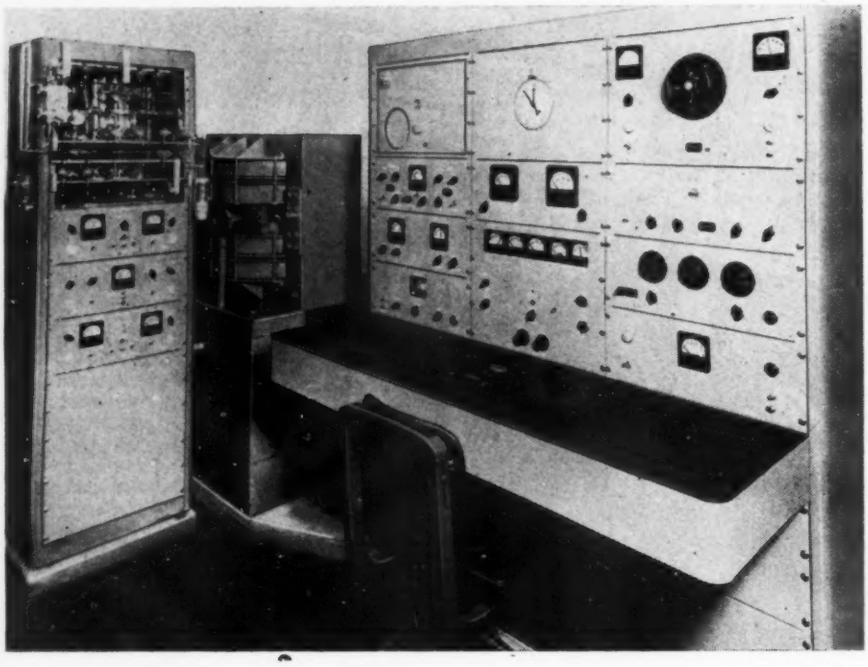


Typical installation of the Consolidated Engineering Corporation mass spectrometer

Use of Mass Spectrometer in Analysis of Refinery Gas Samples*

☆ Theory and operation of instrument—Its performance when used to control an acid alkylation unit

by J. G. Schaafsma

General Petroleum Corporation

UNTIL recently routine gas analyses at the Torrance refinery of the General Petroleum Corporation of California were adequately handled by 4 low temperature fractionating columns with acid adsorption trains for olefin determination. When construction was begun on new plant facilities to meet the growing demand for petroleum products, it became evident that it would be necessary to provide for a large number of additional gas and liquid streams.

After due consideration of factors such as initial cost, accuracy, elapsed time, and man hours required per sample for various types of equipment, a Consolidated Engineering mass spectrometer was installed that now handles all the gas samples. Normally liquid samples, such as gasolines, are still run on the older fractionating equipment. Experience with the instrument over a 3 months' period has demonstrated that it is satisfactory for routine refinery control work in all processes involving light hydrocarbons.

This paper includes a brief discussion of the theory and operation of the instrument, and of its performance when used to control an acid alkylation unit.

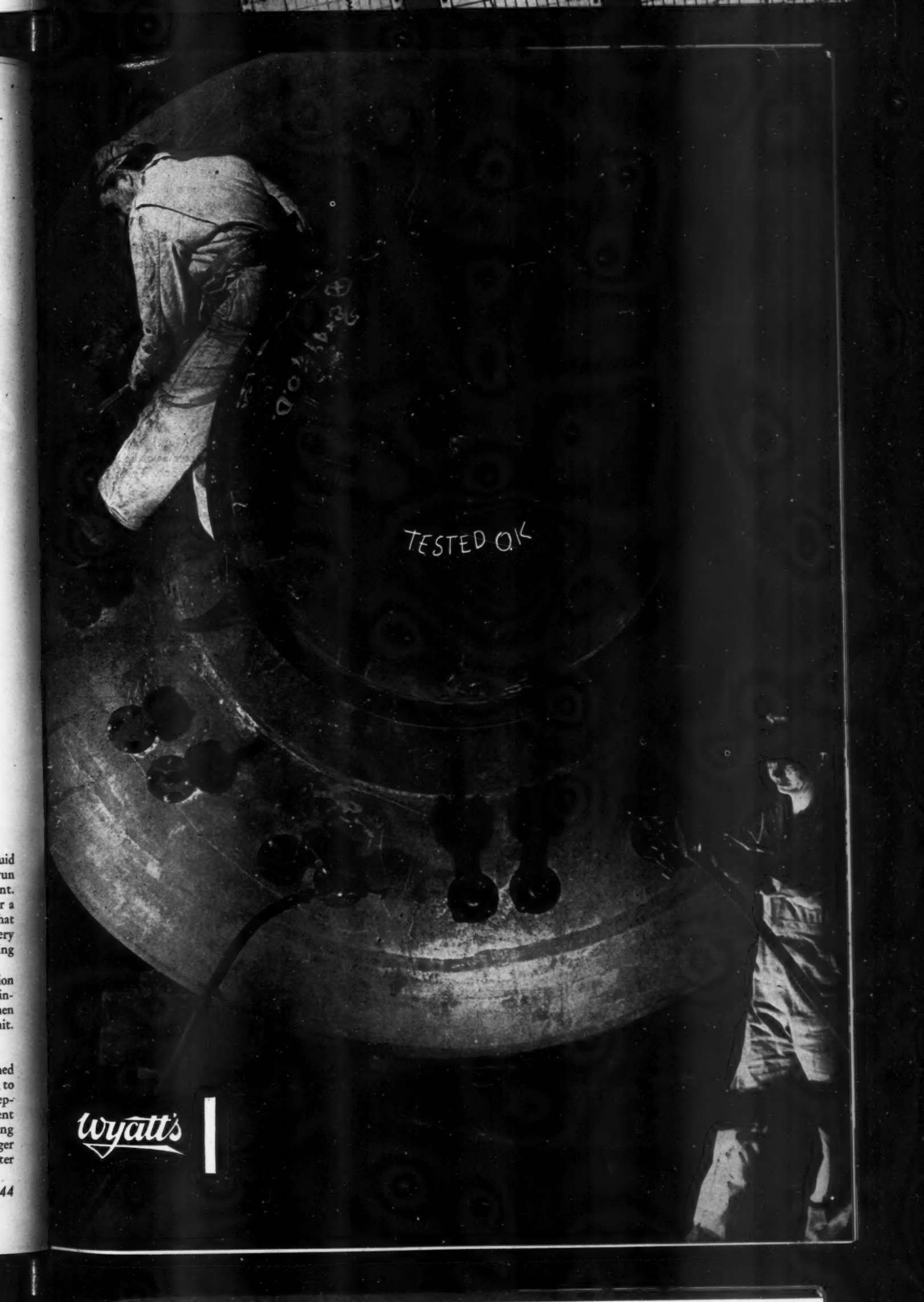
*Paper presented before March 2, 1944, monthly meeting of California Natural Gasoline Association.

THE AUTHOR

Jan G. Schaafsma has been employed since 1934 by the General Petroleum Corporation of California, Los Angeles, as a chemical engineer engaged in process development work—Prior to that time he attended the California Institute of Technology, receiving his B.S. degree in 1932 and his M.S. in 1934—Graduate work there included research in the thermodynamics of hydrocarbon mixtures under the guidance of Dr. B. H. Sage and Dr. W. N. Lacey—His interest in the mass spectrometer arises from participation in certain experimental and practical phrases of recent refinery developments, both of which are materially aided by rapid means of analysis.

General Theory

The mass spectrometer is so named from certain similarities it possesses to an optical spectrometer. The latter separates a light beam into its component monochromatic beams by deflecting shorter wave lengths more than longer ones, whereas the mass spectrometer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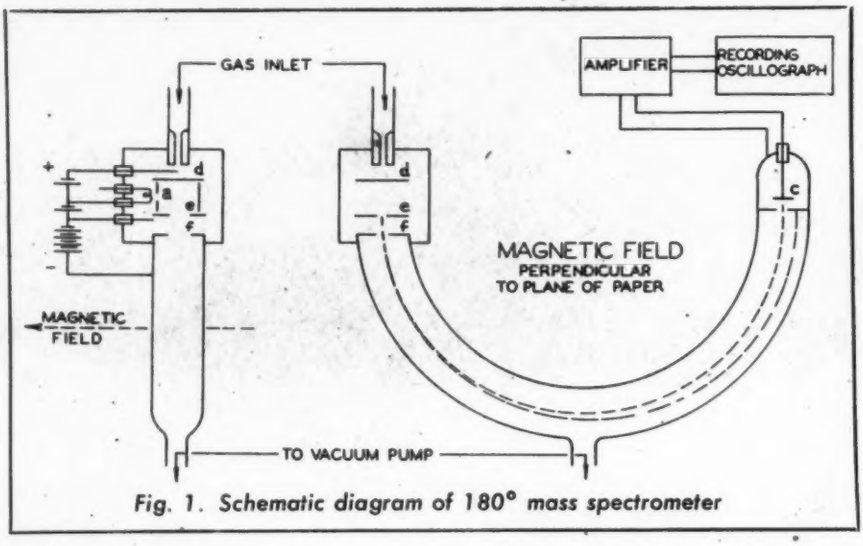

Fig. 1. Schematic diagram of 180° mass spectrometer

separates a beam of moving gas molecules of various types into distinct beams according to mass, the presence and relative percentage of each mass being recorded. In order to obtain this unusual effect, the gas is first ionized and the resultant ions given a high linear velocity by the action of an electric field (between e, f, and g in Fig. 1). Of course, this is done in a high vacuum. Like any other charged particles, the ions can be deflected from their path by passage through the field of a strong magnet. When in the field their paths are curves whose radii of curvature are smaller for the low masses than the high ones. By gradually lowering the electric field producing the initial acceleration, while maintaining a constant magnetic field, the radii of curvature can all be simultaneously and continuously reduced during the course of a run. This means that each mass in turn will have just the right curvature to pass through a semi-circular tube into a slit, and be measured. By keeping the inlet flow rate of gas constant, a record of each mass and of its relative amount can be obtained.

The procedure described would be sufficient if it were not for the existence of isomers of equal mass, such as normal and *iso*butane. In practice the ionization is severe enough to cause partial cracking of the molecules into fragments of lower mass. Each pure hydrocarbon has its own distinctive spectrum, or cracking pattern, as is illustrated by that of normal butane in Fig. 2. Here the parent peak, corresponding to the molecular weight of 58, is evident, as well as peaks due to the decomposition products. The degree of cracking is sufficiently different for each compound to permit the accurate analysis of mixtures containing isomers.

The actual running of a sample is a fairly simple procedure, involving manipulation of a few stopcocks and switches. Scanning and recording of the spectrum is almost completely automatic, the operator's main duties being that of putting a small portion of the gas sample into the inlet system, setting the accelerating voltage at the proper level before the run, and developing the photographic record after the run. As the various electric circuits, such as the magnet and filament currents, are left on continuously, little time is required in preparing for the next run.

Scope of Instrument

Any light hydrocarbon mixture can be analyzed provided that the pure constituents are on hand for calibration. At first only samples essentially free of C_5's were run on General Petroleum's spectrometer, but now *iso*pentane, n-pentane, and total pentenes are regularly determined. Traces of C_6's (0.1 to 1.0 per cent) occur in some of the gases, and can be estimated with sufficient accuracy without going through the complete calculations required to separate these components.

Any samples containing larger amounts of C_6's and heavier are still run on the older fractionating equipment. The presence and percentage of oxygen and nitrogen can be accurately obtained, and as time permits, it is planned to try analyzing for hydrogen sulphide and the light mercaptans as well. CO_2 interferes badly with certain hydrocarbon peaks and is removed beforehand. Water cannot be determined because of its absorption on the glass walls of the apparatus. The accurate separation of hydrogen and methane is easily made, whereas the older equipment gave only an approximate split.

Accuracy

From experience gained to date it appears that the spectrometer is at least as accurate in all respects as a very carefully operated fractionation and acid absorption system, and considerably better than the latter as ordinarily run in routine control work. Table 1 contains comparisons between the two methods of analysis for two refinery gases and a spectrometer analysis of a synthetic mixture of known composition. Results obtained by the spectrometer check very closely with the analysis of the synthetic mixture and with results from conventional gas analyses.

Another test is shown in Table 2, in which General Petroleum made up a synthetc mixture and ran it through the spectrometer. From this record Consolidated and General Petroleum each independently calculated the analysis, as shown in the table. Again the accuracy is satisfactory. Other work has demonstrated that the spectrometer can determine small amounts, say 0.1 to 0.3 per cent of heavy ends such as pentanes or hexanes, in cases in which the conventional method shows none present.

The mass spectrometer produces a permanent record practically independ-

(Continued on Page 142)

TABLE I

Comparison of results of gas analyses by combined fractionation and acid absorption and by the mass spectrometer

Gas analyzed....	Cracking unit absorber release gas		Cracking unit stabilizer release gas		Synthetic gas sample	
Torrance lab. no..	3069		3062			
	Mass spectrometer	Fractionation and absorption	Mass spectrometer	Fractionation and absorption	Mass spectrometer	Actual composition‡
H_2S.....	not determ.	0.08	not determ.	0.22	0	
N_2.....	1.6	....	0.2	0.00	0	
H_2.....	10.7	....	0.2	0.00	0	
Methane.....	56.1	66.70†	9.6	7.89	0	
Ethene.....	2.7	2.37	1.8	1.69	0	
Ethane.....	18.6	20.34	22.5	22.28	20.9	21.0
Propene.....	3.2	2.78	14.9	14.56	12.8	13.1
Propane.....	6.0	6.59	37.7	39.67	35.7	35.8
*Iso*butane.....	0.6	0.65	4.7	4.65	6.6	6.2
*Iso*butene.....	0.4	0.38	3.7	3.78	4.7	5.1
N-butene.....		0.11	2.7	2.79	6.9	6.4
N-butane.....			2.0	2.47	12.4	12.4
Total.....	99.9	100.00	100.00	100.00	100.00	100.00

†Includes fixed gases.
‡Pure compounds blended, amounts added being read on a manometer.

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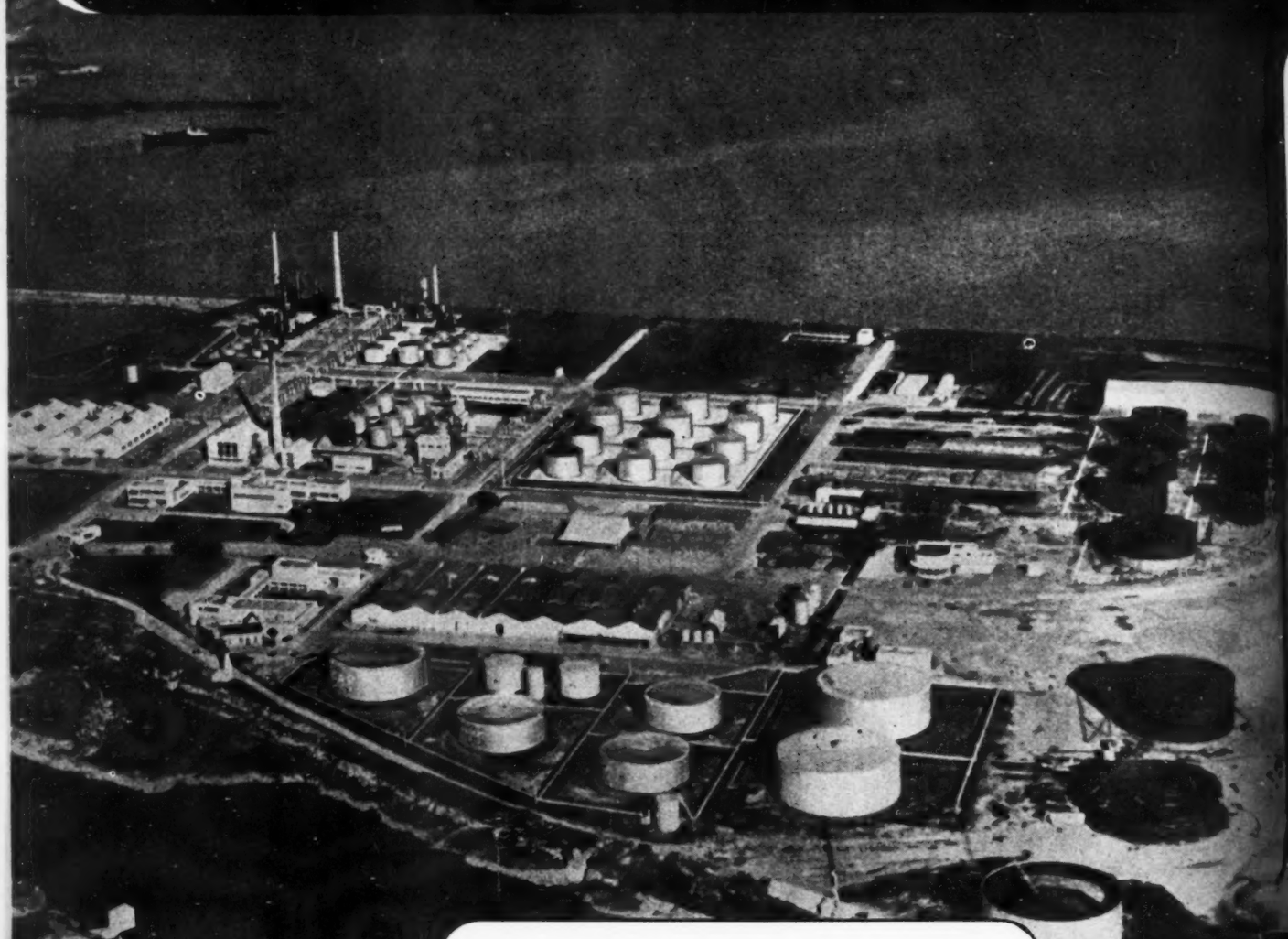

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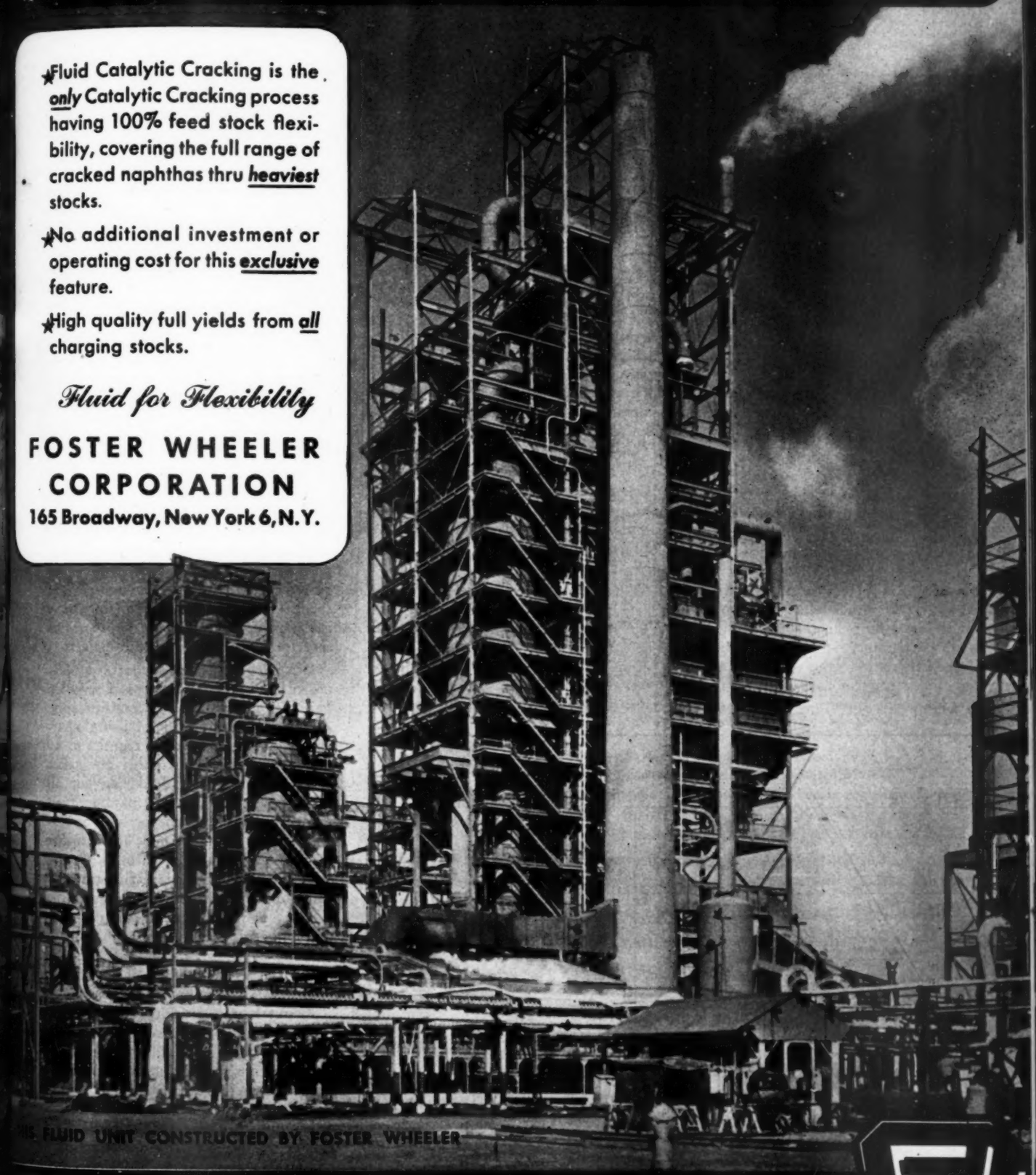

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TABLE 2

	Synthetic per cent composition	Consolidated calculation per cent	General petroleum calculation per cent
Methane	14.88	14.90	14.90
Ethane	19.96	19.94	20.05
Propene	10.07	9.98	10.10
Propane	20.07	20.14	19.92
Isobutane	9.97	9.96	9.87
Isobutene	6.99	6.67	7.23
Butene—1	5.03	5.07	4.82
Butene—2	4.98	5.38	5.05
N-butane	8.05	7.96	8.06

(Continued from Page 138)

ent of the skill and judgment of the operators, which is not true of older methods of gas analysis. In case results appear doubtful, it is only necessary to check the calculations and not the run.

Methods of Analysis

Although essentially a scientific instrument capable of turning out precise results, the nature of the spectrum obtained is such that in many cases the approximate percentage of one or two components can be obtained by a rapid inspection of the developed record. This is possible because in many refinery mixtures there are compounds whose main peaks on the record contain no contributions from other compounds. The heights of these peaks are directly proportional to the percentage of the compound in the mixture, which makes their analysis very simple. A complete analysis is usually more involved than this because many of the peaks consist of contributions from a number of compounds. Contributions of each compound are always directly proportional to its percentage, however, and much of the calculation involves only arithmetic. For the rigorous solution of a 14-component mixure consisting of a highly cracked gas containing all hydrocarbons through the C_4's as well as hydrogen, air, and H_2S, the most complicated mathematics required is the solution of a set of 3 linear simultaneous equations.

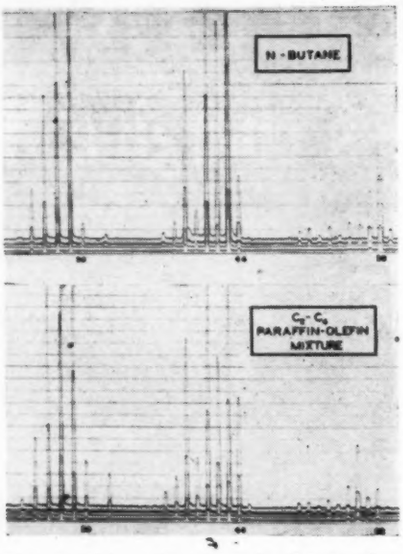


Fig. 2. Automatic records obtained on the mass spectrometer

Short methods of analysis are especially applicable when a refinery operation can be controlled on the basis of one or two key components. For example, in a depropanizer purifying *iso*butane the overhead need only be analyzed for *iso*butane and the bottoms for propane. When such a case exists, two short cuts can be used to reduce computing time and instrument time, respectively.

The first consists in obtaining a complete record in the spectrometer and obtaining the percentage of the key component by inspection or a short calculation. At any future time the complete analysis may be computed, if required, from the record that is filed. Instrument time can be reduced by scanning a part of the spectrum and procuring only that part of the record needed to determine the key component. No complete analysis can be calculated in the future, however.

Calculation by inspection is especially useful in determining the percentages of small amounts (up to 5 per cent) of undesirable heavy constituents caused by improper operation of refinery equipment. An experienced spectrometer operator can become quite proficient and accurate in this useful shortcut, as the heaviest fractions, say hexanes, produce peaks that stand out by themselves and are due to no other compounds.

All these partial analyses give the composition as mol percentages. In case the analysis of a liquid stream, say a C_4 cut, is desired in terms of liquid volume percentages, a complete analysis of the cut on a molal basis must first be worked out. It would seem desirable to convert refinery operations to a mol percentage basis whenever possible.

Time Needed

Depending on the type of gas and the accuracy desired, results can be reported within from 25 min. to 2 hr. after receiving the sample. Considerable time can be saved when only the approximate percentage of one key component is required by the refinery, as an experienced spectrometer operator can, in many cases, procure this figure by mere inspection of the photographic record.

Actual instrument time is usually under 30 min. for all types of samples, but calculation times vary considerably. Accurate determination of a single paraffinic constituent varies from 5 to 10 min., depending on whether an *iso*mer is present or not. Calculation for all components of a C_1 to C_4 paraffinic gas takes 30 min., and the present of *iso*- and normal pentanes may add another 10 min. A cracked C_1 through C_4 gas requires about 1-hr. calculating time because of the presence of olefins, and the presence of appreciable amounts of pentenes may add from 15 min. to 1 hr. to the time depending on whether they are calculated as a total or as individual pentenes.

About 1 hr. a day, prorated, is spent in calibration of the instrument. Actually, a complete calibration for all hydrocarbons need be run only once in 2 weeks, whereas a daily check is made on n-butane alone. This latter run requires under 30 min., as the equipment is kept warmed up overnight when not running 3 shifts.

The shortest type of run is illustrat-

TABLE 3

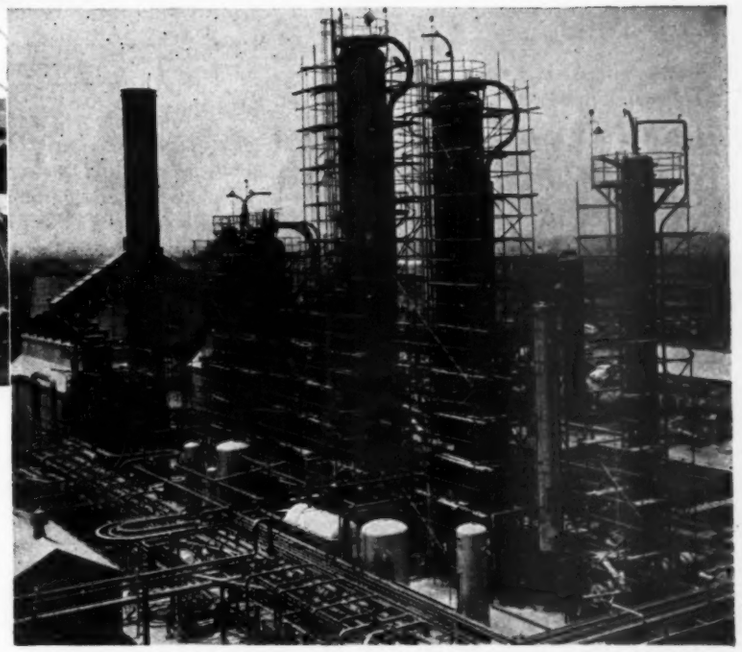
Hydrocarbon samples from gas plant and alkylation unit

Type of analysis used and time required when alkylating butenes and pentenes together

	Type of analysis*	Key components	Total elapsed time for run and calculations: Complete for all components	Total elapsed time for run and calculations: For key components only, using short cuts
Gas plant				
Total gas from SR and cracking units to h.p. absorber	MS	n-pentane	105 min.	45 min.
Gas from h.p. absorber	MS	C_4's	45	30
Gas from l.p. absorber	MS	C_4's	45	30
Raw B-B depropanizer feed (from gas plant) incl. C_3's	MS	All	85	85
Raw B-B depropanizer tops	MS	C_4's	45	30
Raw B-B depropanizer bottoms, incl. C_5's	MS	C_5's	85	30
Raw B-B debutaniser—tops	MS	n-pentane	85	60
Raw B-B debutaniser—bottoms		pentenes	..	60
Alkylation unit				
Treated B-B to contactors, incl. C_3's	MS	All	85	85
Recycle isobutane	MS	propane and isobutane	60	40
Alkylate de-isobutaniser—feed	fractionation	C_3's, C_4's	480	..
Alkylate de-isobutaniser—tops	MS	n-butane	45	35
Alkylate de-isobutaniser—bottoms	fractionation	isobutane	360 (thru C_5's)	90
Alkylate debutaniser—tops	MS	isopentane	35	25
Alkylate debutaniser—bottoms	fractionation	n-butane	300 (thru C_5's)	90
Isobutane depropaniser—tops	MS	isobutane	35	25
Isobutane depropaniser—bottoms	MS	propane	35	25
Alkylate rerun—tops	fractionation	C_5's	..	120

*M.S.—Mass spectrometer; fractionation—low temperature fractionation and acid absorption.

The Unwritten Specification



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ed by the testing of a depropanizer overhead for *iso*butane inclusion. In this case instrument time is reduced by operating over a limited range of masses (from 40 to 60).

	Elapsed time
Introducing sample	5 min.
Making run	10 min.
Developing	5 min.
Calculation by inspection	5 min.
	25 min.

A complete analysis of a cracked gas containing no pentanes would require the following time:

	Elapsed time
Introducing sample	5 min.
Making run from mass 10 to mass 66	20 min.
Making run from mass ½ to mass 4 (H_2 requires weaker magnetic field)	5 min.
Developing	5 min.
Calculation for all components	60 min.
	95 min.

This calculating time is for an expert well adapted to this type of work.

Man Hours

In addition to saving time through calculation by inspection, some savings are obtained if only total butenes rather than the breakdown into *iso*mers is desired. When most refinery operations are controlled on the basis of one or two components, and speed rather than extreme accuracy is desired, 2 operators and 1 calculator can turn out an average of 14 refinery samples containing C_1 through C_4 in an 8-hr. day, when half of them are calculated by inspection. This is equivalent to 1.72 man hours per sample.

If all samples are to be accurately calculated for all components through C_4's, one more calculator must be employed and the man hours become 2.28 man hours per sample. The presence of appreciable amounts of pentanes increases the calculating time and hence the number of calculators needed. The number of samples per day put through the machine may be increased in certain cases when most of them can be run over a limited range of masses instead of over the whole range from C_1 through C_5.

Table 3 shows a list of samples from a gas plant and alkylation unit, showing time required for complete and for partial analyses. In order better to illustrate the range of samples that can be handled by the spectrometer, this example shows some pentenes included in the *iso*butane-olefin charge to the alkylation unit contactors, although this is not a general practice. Some of the streams containing appreciable amounts of hexanes and heavier are still run on the fractionating equipment, as they are at present considered too complicated for routine analysis by the spectrometer. Other laboratories, however, have analyzed certain C_6 and C_7 concentrates by means of the spectrometer.

Personnel

It is considered desirable to have two operators per shift for satisfactory performance and one or more calculators, depending on the type of samples run. In our case the operators are college graduates with considerable petroleum laboratory experience. It is desirable in any case for at least one person to have a good technical background and that all operators be chosen for their skill and technique in handling precision equipment. One operator puts the sample through the instrument and watches the controls, while the other connects and disconnects the sample bombs, develops the records, and assists in the calculations as time permits.

At Torrance, calculations are handled by a girl with no training except first year high school algebra. Speed and accuracy are the desirable traits in this case, the calculations being detailed but not at all difficult. About two months are required to break in a calculator, although much of the work can be picked up in a few days. An aptitude test might be advisable to be sure of obtaining persons well suited for this work.

Maintenance work requires the part-time services of a skilled electrician. Repairs here are made by a refinery electrician with the help of one operator who has familiarized himself with the various electrical circuits. In case of failure of the analyzer tube or a galvanometer, the repair work is done by Consolidated Engineering Corporation in Pasadena. Delays are avoided by keeping a spare tube and one galvanometer on hand that can be installed by the operators.

Sampling

Due to the extremely small amount of gas actually required for a run (less than 1 cc. of gas at one atmosphere) the size of the sample is dictated by convenience. At Torrance 6-oz. ICC cylinders are used for high pressure samples and glass containers for gases at atmospheric pressure. Both types are equipped with two valves for filling by water displacement.

A more complete discussion of the technical details of the spectrometer may be found elsewhere and also of the experiences of others in the use of the instrument.* The writer is indebted to D. J. MacLaren for preparation of the data used in this report and to the Consolidated Engineering Corporation for permission to publish this article.

*H. W. Washburn, H. F. Wiley, and S. M. Rock, *Ind. and Eng. Chem.* Anal. Ed., Vol. 15, No. 9, p. 541, September, 1943.
O. L. Roberts, The Atlantic Refining Company, *The Petroleum Engineer*, Vol. 14, No. 8, p. 109, May, 1943.
O. L. Roberts, The Atlantic Refining Company, *Petroleum Refiner*, Vol. 22, No. 5, p. 107, May, 1943.

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Analyses of Crude Oils From West Texas Fields

P 261.

ANALYSES of crude oils from 43 West Texas fields have been compiled by the U. S. Bureau of Mines to facilitate the possible use of these crudes by refiners who customarily employ Mid-Continent oil as charging stock. The compilation was prepared in response to requests from the petroleum industry, Dr. R. R. Sayers, director of the Bureau, said.

Heavy use of Mid-Continent crude oil for the manufacture of war products, particularly aviation gasoline and lubricating oil, has caused an acute shortage of available supplies from established sources and refiners who previously have not used West Texas crudes now are considering these oils to help meet wartime demands for petroleum products.

Fields covered in the Bureau's summary are: Apco, Big Lake (Queen), Big Lake (Dolomite), North Cowden, Crane-Cowden, Dune, Embar-Ellenberger, Foster (Big Lime), Foster (Dolomite), Fuhrman, Fullerton, Goldsmith, Harper, Hendrick, Howard-Glasscock, Iatan-East Howard, Jordan, Kermit, Keystone, Leck, McCamey, McElroy, Means, Payton, Pecos Valley (Yates Sand), Pecos Valley (Pecos Valley Sand), Seminole, Scarborough, Shipley, Slaughter, Snyder, Taylor-Link, Tobarg, Waddell, Ward, South Ward, Wasson (San Andres), Wasson (Wasson 72), Wasson (Clear Fork), Westbrook, Wheat, World, and Yates.

The analyses were made under the supervision of R. A. Cattell, chief of the Bureau's Petroleum and Natural Gas Division; N. A. C. Smith, supervising engineer at the Bureau's Petroleum Experiment Station, Bartlesville, Oklahoma; and Harold M. Smith, senior petroleum chemist at Bartlesville. The tabulation was prepared by Boyd Guthrie, petroleum chemist at Bartlesville.

A copy of the publication, Report of Investigations 3744, "Analyses of Crude Oils From Some West Texas Fields," by Boyd Guthrie, may be obtained by writting the Bureau of Mines, Department of the Interior, Washington 25, D. C.

☆ ☆ ☆

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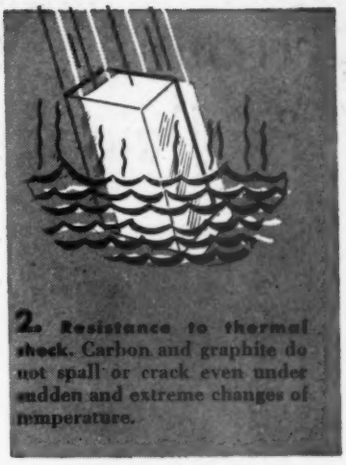
THE Carbon and Graphite and "Karbate" materials manufactured by National Carbon Company possess chemical and physical properties ideally suited for many applications in the chemical and process, petroleum, metallurgical, textile, electrical and mechanical industries. A choice of grades, with or without several processing treatments, will meet specific conditions requiring a *combination* of properties found exclusively in these materials.

A few of these properties are illustrated on this page. A careful study of these will reveal applications assuring trouble-free operation and low maintenance cost. National Carbon Company engineers will be glad to consult with you on your problems.

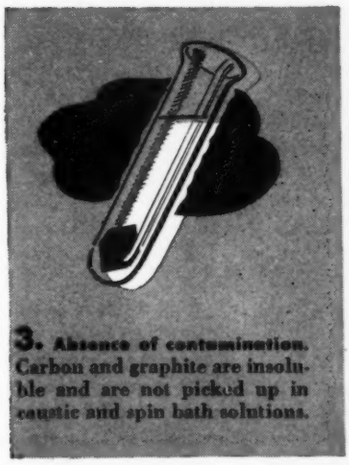
The word "Karbate" is a trade-mark of National Carbon Company, Inc.

★ *BUY UNITED STATES WAR BONDS* ★

1. Corrosion resistance. Carbon and graphite are inert to all but highly oxidizing conditions, and to most acids, alkalies and solvents.

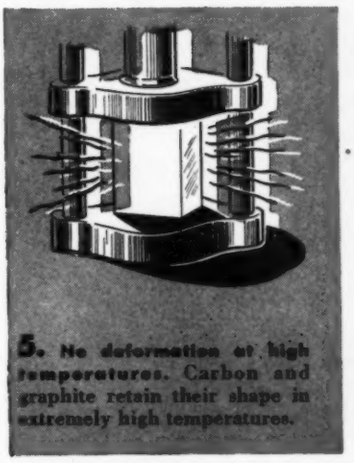


2. Resistance to thermal shock. Carbon and graphite do not spall or crack even under sudden and extreme changes of temperature.

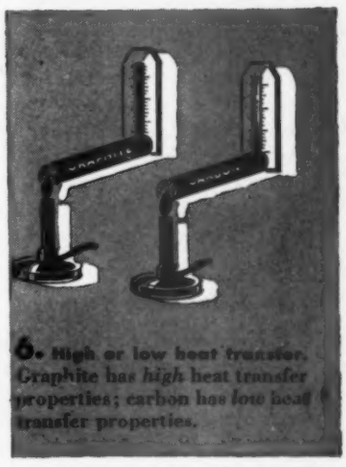


3. Absence of contamination. Carbon and graphite are insoluble and are not picked up in caustic and spin bath solutions.

4. Ease of fabrication. Carbon and graphite are readily machinable to intricate shapes and close dimensional tolerances.



5. No deformation at high temperatures. Carbon and graphite retain their shape in extremely high temperatures.



6. High or low heat transfer. Graphite has *high* heat transfer properties; carbon has *low* heat transfer properties.

7. Not wet by molten metal. With carbon and graphite, molten metals flow freely without slagging or sticking.

8. Electrical conductivity. Carbon and graphite have various degrees of conductivity for a very broad range of electrical conditions.

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Training Within Industry—Supervisory Proficiency Affects Production

PETROLEUM ENGINEER Exclusive Feature

☆ Program instituted for all industry proves its specific value to the petroleum industry

by R. S. Driver

Director, Training Division, The Atlantic Refining Company

THREE and a half years ago, Owen D. Young, among others, recognized the need for better training within industry. As a result of the interest of such men, a service of industry, by industry, and for industry, was formulated and called "Training Within Industry." Channing Dooley, director of industrial relations, Socony-Vacuum Oil Company, was borrowed to become director of this service. Walter Dietz, Western Electric Company, William Conover, U. S. Steel Company, Michael Kane, A. T. & T. Company, Long Lines Division, were borrowed from their companies to assist Dooley. Since that time, Training Within Industry has functioned as a unit to provide advice and assistance in the soluton of training problems in any war industry. A year after the organization of this service, it became obvious that in addition to assistance of an advisory nature, it was also necessary to prepare intensive training plans, which could be used in any industry and which would give supervision sufficient skill to enable them to solve the problems then and now confronting them.

Three Training Plans

These intensive training plans, which have been popularized by Stewart Chase in his recent articles in the *Readers' Digest*, are known throughout the country as JI, JR, and JM. JI is a planned way of giving supervisors skill in instructing workers in their jobs. JM is a different plan, designed to give supervisors skill in improving methods of work. JR is a third plan, which provides supervision with skill in dealing with individuals. Each of these three training plans has been streamlined to meet war conditions and can be presented in 10 hours to groups of supervisors.

The job instruction program was the first of the three 10-hour plans developed. The other two, the job methods program and the job relations program, as well as JI, were designed to develop basic skills of paramount importance needed by all supervisors. As of this writing, more than 14,000 firms in the United States have conducted these plans for their supervisory personnel. The resultant saving in the time required to bring workers up to production standards has been reported to be from 5 to 90 per cent, the average saving being between 35 and 40 per cent. Such a saving has been a real contribution to production, conservation of manpower, and the reduction of machine hours, scrap, and accidents. Likewise, it is of interest to note that most firms that have taken advantage of this part of the program report find it is just as effective when used with the more experienced as well as with the new supervisors.

The content of the JI plan is not new. It has been developed over a period of the last 25 years by practical industrial men in this field. The manner in which these principles are presented and the organization of the material is new, however. It has been streamlined so that a maximum result can be accomplished in a minimum of time. Job instruction, like the other two programs, is presented in a series of five 2-hour conferences with 10 to 12 supervisors in attendance. Obviously, the higher levels of supervision must participate before the material is discussed with the lower levels.

The leaders of these conferences must be competent industrial people who have been trained to present the program by Training Within Industry. Such individuals should be drawn from

The men who put Training Within Industry service into practice: William Conover (left); Channing Dooley (standing); Michael Kane (seated), and Walter Dietz

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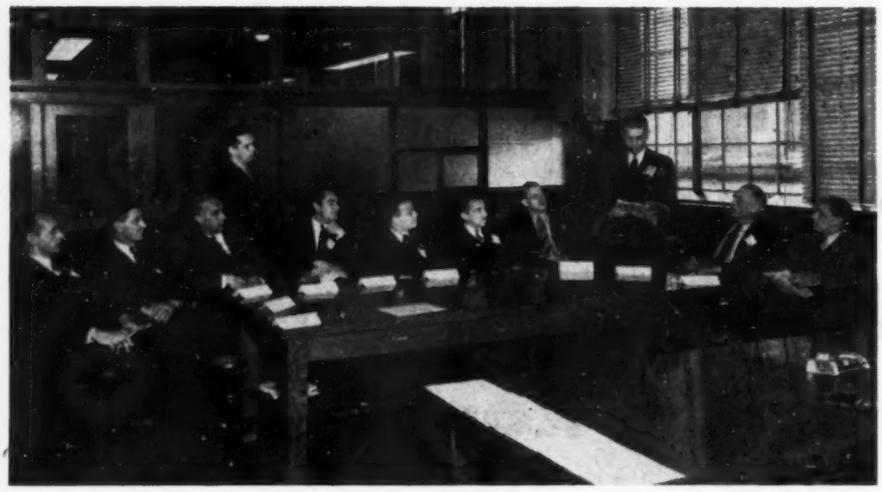

A JM Institute held at General Electric with representatives from other companies also present

the personnel of the particular company in which the training of supervisors is to take place. Occasionally, however, to very small companies where it is impossible to accomplish the training in this fashion, Training Within Industry will make available part-time trainers.

The petroleum industry has utilized these three "J" plans in many aspects of the business, including transportation, marketing, refining, producing, and the attendant clerical phases of the operations. During the past year in my contacts with this industry from coast to coast, including the Gulf Coast area, I found these programs in use in almost all the major companies and in many of the smaller organizations.

Job Instruction

One East Coast refinery has used Job Instruction to a considerable extent, and although the obvious purpose was to produce supervisory skill leading to better instruction, the tangible effects of the training were most noticeable in the safety record of the organization. The fact that the lost time accidents were considerably reduced after such training, and that the safety director attributed a large part of this to Job Instruction is not surprising, in view of the fact that a man who is properly instructed to do a job the safest way will undoubtedly be a safer worker. Job Instruction, as used by one Gulf Coast refiner, will be extended to almost all workers in the plant. This is a realistic approach to the problem, in view of the fact that most of the actual instruction in almost all the refineries is given by people who are not classified as supervisors, but who exercise minor supervisory control, in that they are responsible for breaking in inexperienced workers on lower grade jobs, such as a sampler.

Job Methods

Job Methods is designed to assist supervisory personnel in simplifying work procedures, in order to make the best use of the manpower, equipment, and material now available. In practice, this program encourages cooperation between line supervisors and the engineering, methods, and production planning departments. Those petroleum companies that have this program under way have experienced astonishing results, as attested to by the following examples.

One West Coast company has made particularly effective use of Job Methods by giving it to more than 200 supervisors in its refinery. The constructive improvements that have resulted from these programs have been astounding, particularly in view of the fact that the refineries of most plants are so well engineered. These improvements have been developed by supervisors in such departments as the refinery, lubricating, package, and shipping, and all phases of maintenance work.

Another petroleum company has used JM extensively. In the office of this particular company, all office supervisors have been trained and asked to review a portion of the essential parts of the jobs under their supervision. Here again the results were highly gratifying, in that a substantial saving in man hours was achieved by the elimination of useless work and the simplification of the office methods in connection with other phases of the work. Such results are evidence of the fact that supervisory skills of the type developed by these "J" plans can be used in all phases of the petroleum industry.

Job Relations

Job Relations provides supervision with a method for solving problems that confront all supervisors. T. W. I. has found that virtually all supervisors in every company want to know how best to handle the every day problem of human relations that confronts them. Experienced and able supervisors have worked out this JR method which, if applied, is found useful in all cases. This method again has been organized in such a manner that it can be presented and practiced by supervisors during five 2-hour sessions. During the first 2-hour meeting the leader presents the JR method and during the rest of the five meetings each member of the group applies it to one or more of the problems that face him, or possibly one that he has handled during the last 30 days. In this way, supervisors are developing habits for handling problems of human relations.

Job Relations has been particularly attractive to the oil industry and has been widely used. This is the newest of the three plans, but it is so fundamental in nature that its value has been immediately recognized. The effects of such a plan in the oil industry have been measured in some instances by noting a reduction in the number of grievances, a reduction in turnover and absenteeism, and in some cases by a noticeable improvement in morale. At the present time, JR is most widely used in the West Coast and East Coast areas. It was introduced to the Gulf Coast in the fall of 1943 and gives every indication of spreading to many of the companies in that area.

Conclusion

Those familiar with these training plans know that they bring immediate results. However, experience causes Training Within Industry to insist that management realize that such programs will be but "shots in the arm" and their value restricted unless management insists that they are properly followed through by the operating departments as part of their daily responsibilities. Training Within Industry service daily is pointing out that management must realize that training is a tool of production and therefore a major responsibility of management.

The service of Training Within Industry is free to all units of the petroleum industry having direct or indirect contracts for the production of war materials. Anyone desiring specific information concerning this service should communicate with the nearest district office of Training Within Industry, which is now a branch of the War Manpower Commission. Such offices are in almost all the principal cities throughout the country.

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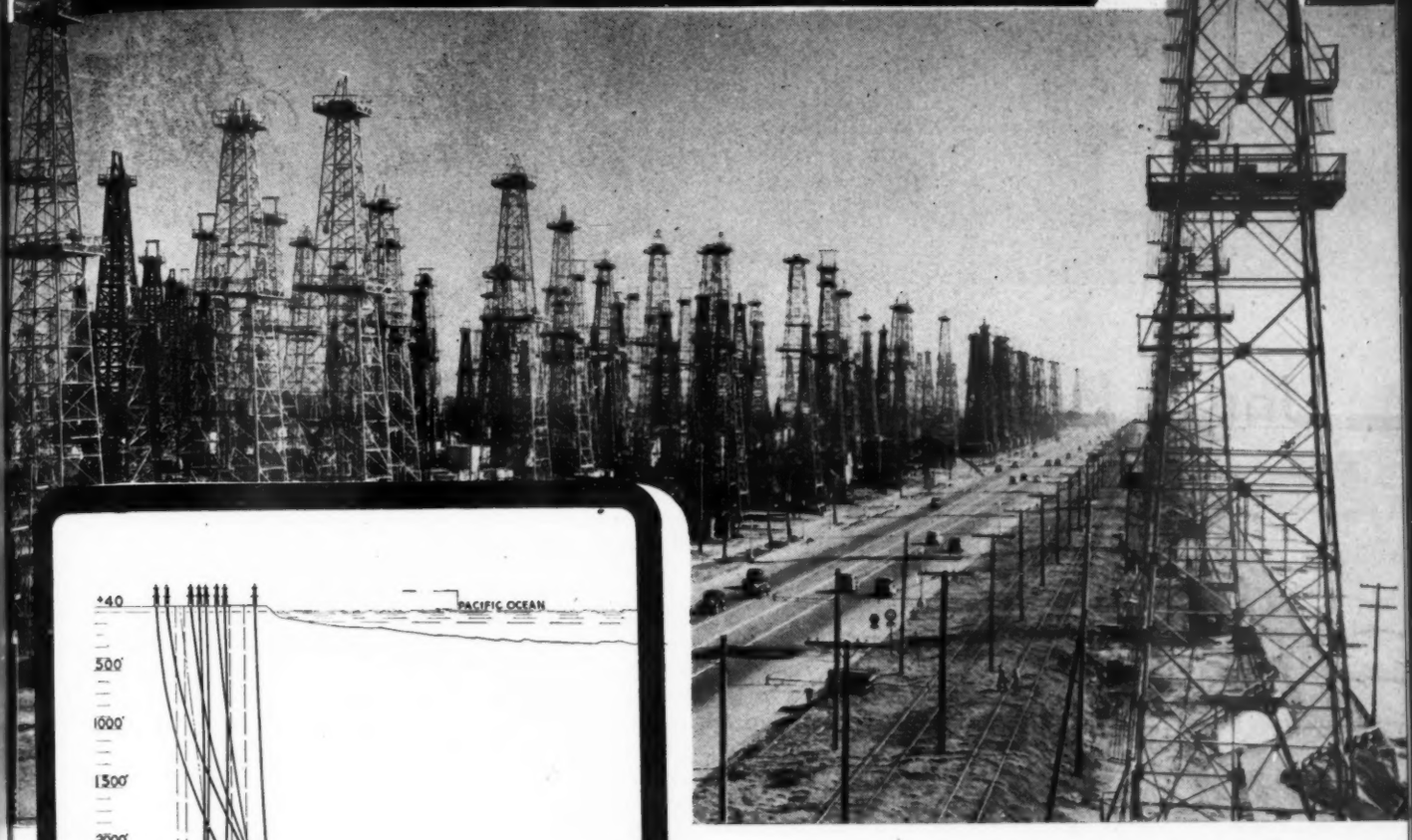
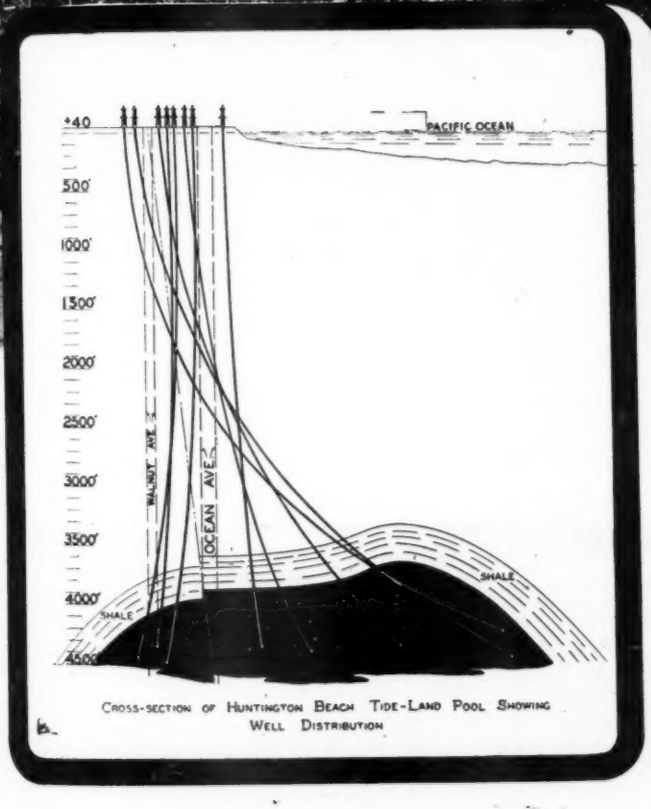
57 MILES OF *Deflected* HOLE TAPS OCEAN OIL RESERVES

ANOTHER MARVEL OF *Eastman* DIRECTIONAL DRILLING





CROSS-SECTION OF HUNTINGTON BEACH TIDE-LAND POOL SHOWING WELL DISTRIBUTION

Coastal View of Huntington Beach, Calif., Oil Field
Photo courtesy of The Inman Co.

Huntington Beach, California, one of the world's richest oil fields, is the scene of approximately **166** deflected wells, drilled to tap a portion of the field which underlies the ocean. A total of **66** miles of horizontal deflection was necessary to accomplish this unusual development, in a total of **157** miles of drilled hole.

In some wells, a deflection of **3770** ft. was required to achieve the objective. The angle of deflection reached as high as 70 degrees in some instances. A total gain of **53,784** ft. of oil sand or an average gain of **324** ft. per well was the result of wells penetrating the oil sand at an angle, thus actually increasing the amount of oil sand exposed to the bore hole.

New horizons which formerly could not be reached profitably, and new sub-surface problems are now being solved through Directional Drilling and Directional Surveying.

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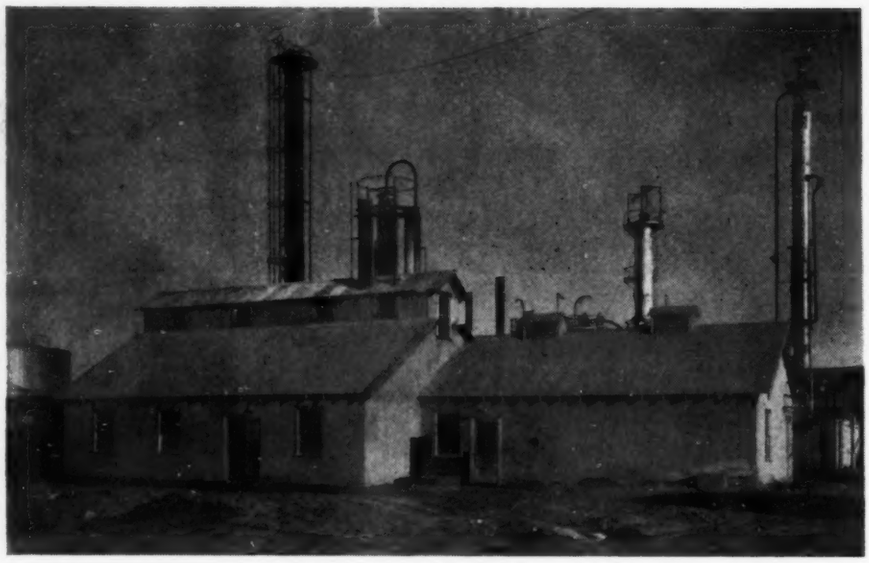


Building housing the Unisol unit; towers extend through roof

by
F. C. Moriarty
Universal Oil Products Company

Unisol Process for Treating Gasoline

☆ Mercaptans removed by extraction with concentrated solution of caustic soda containing methanol

FOR more than 18 months a Unisol treating unit has been operating in the refinery of the Big West Oil Company at Kevin, Montana, and is accomplishing important results. The Unisol process, licensed by Universal Oil Products Company, removes mercaptans by extraction with a concentrated solution of caustic soda containing methanol. It is used to treat the gasoline produced by the Dubbs cracking unit in the refinery.

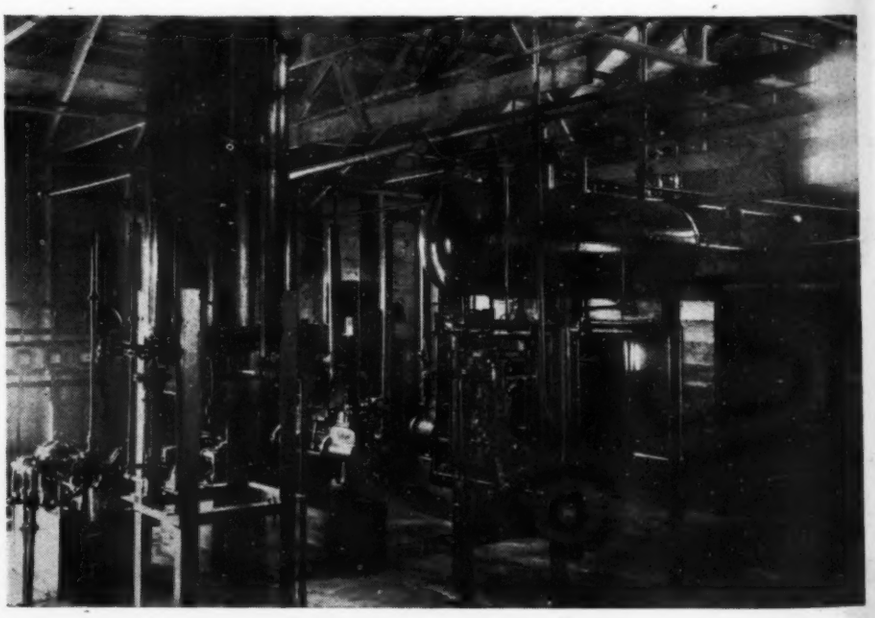
Before the Unisol process was installed the gasoline had been treated by doctor sweetening, which was an expensive operation. It reduced the octane number from 1 to 2 points and caused a rather large loss of gasoline. The new process was adopted to reduce these losses as well as to eliminate mercaptans, and by so doing improve the tetraethyl lead susceptibility of the gasoline.

The operation of the Unisol unit has more than justified expectations. The mercaptan content of the gasoline is being reduced from 0.06-0.11 per cent to an average of 0.0007 per cent as it leaves the treating unit, and it usually becomes doctor sweet, or nearly so, after standing a few days in storage.

Increases Octane Number

As soon as the operation was well under way, Big West shut down the doctor sweetening unit. In contrast to the loss of 1 or 2 octane numbers caused by doctor sweetening, the Unisol treating has increased the unleaded octane number by one-half point. The reduction in mercaptan content is accompanied by a corresponding reduction in total sulphur and a substantial increase in tetraethyl lead susceptibility. Prior to the operation of the Unisol unit, ethyl grade gasoline (then 80-octane number) could not be produced in the Big West plant. After treating, the addition of 3 cc. of tetraethyl lead per gal. to the cracked gasoline makes an 80 plus octane product.

Of greater importance to Big West is the fact that the increase in tetraethyl lead susceptibility makes it possible to blend all the straight-run gasoline with the cracked product and produce house brand gasoline. When operating the doctor sweetening unit, it was necessary to add 1.1 cc. of tetraethyl lead to the cracked gasoline to reach 74-octane number. If any substantial quantity of straight run was blended with the



Methanol column receiver and mercaptan separator

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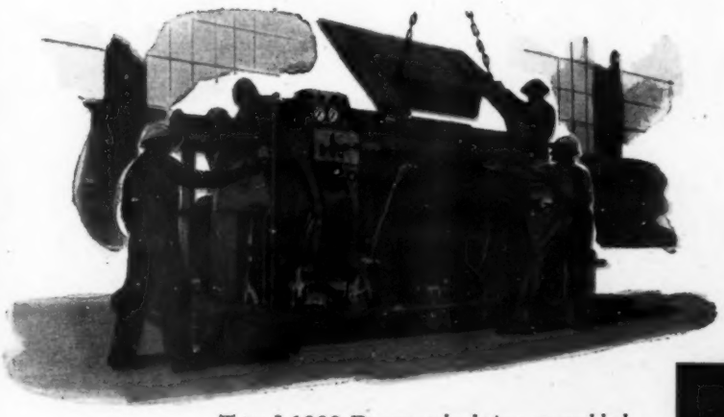

Type J-1000 Drawworks being assembled and factory checked before shipment.

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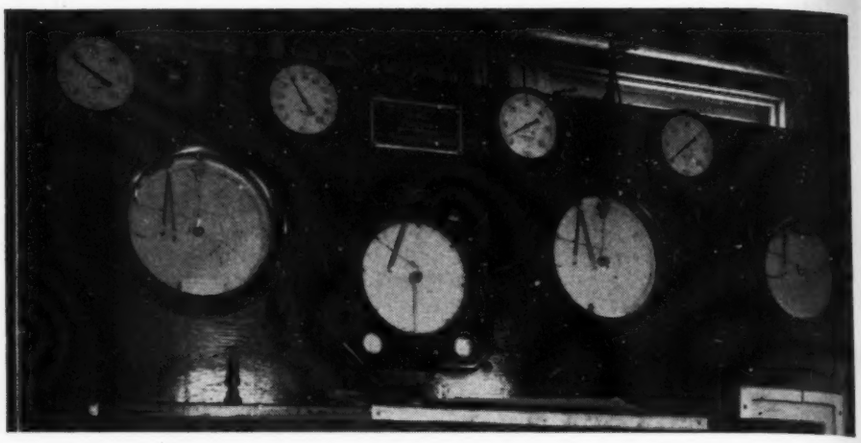

cracked gasoline it could not be brought to 74 octane. By contrast, a typical sample of Unisol-treated cracked gasoline, when blended with 10 per cent straight run and 0.65 cc. of tetraethyl lead, made 75-octane number.

Less Gasoline Loss

The overall cracking and treating loss of gasoline for a 9 months' period before the Unisol unit went into operation had been 9 per cent. The loss over 9 months following the installation of treating was 5.9 per cent, or a reduction of 3.1 per cent.

Some of this reduction in loss may have resulted from minor changes in the cracking unit but it is believed that at least 50 per cent of the reduction can be credited to the operation.

The original loss was high because of deficiencies in the doctor sweetening operation. Such deficiencies are common to many doctor sweetening units and are aggravated when a gasoline high in mercaptan content is processed.

Analysis of the mercaptans separated from the gasoline shows only a trace of dissolved hydrocarbons. This proves that the loss in treating is insignificant, inasmuch as any gasoline loss would appear in the mercaptan oil.

Cost of Reagents Low

The Big West unit processes approximately 550 bbl. of gasoline a day. It is to be expected that losses of reagent in a plant of that capacity would be greater proportionately than in a larger unit, as the smaller unit has the same number of packing glands, sample valves, etc., as the larger one. Nevertheless, the Big West unit consumes less than 2 gal. per day of methanol, and the total cost of reagents is well below one-half cent per barrel treated. Labor costs, too, are low, as only part of the time of one operator per shift is necessary.

There have been no process difficulties; however, corrosion in the bottom of the caustic recovery section, which is made of carbon steel, is so severe that it was necessary to replace a 24 in. by 10 ft. section after 8 months' service, and it has been necessary to repair it several times in addition. This section is flanged to make replacement easy, and thus has not been a serious handicap to operation of the unit, which to date has made a number of runs well over 100 days in duration. Nickel-clad steel will completely eliminate the corrosion problem as soon as it is again available.

Cold No Obstruction

Although the Big West unit is situated in northern Montana, where extremely low temperatures prevail in winter, no difficulties have been encountered in operating the process, even under subzero weather conditions.

The inhibitor susceptibility of the treated product is excellent. The addition of 0.007 per cent of U.O.P. inhibitor No. 4 to the finished gasoline increases the induction period by approximately 250 min., and the copper dish gum (Atlantic method) of the inhibited gasoline has been consistently below 10 mg.

The management of Big West was foresighted in recognizing the need for such a unit and had the initiative to gamble $20,000 on an installation at a time when no commercial experience with this process was yet available.

The saving of tetraethyl lead in gasoline, together with the appreciated value of the product and decrease in gasoline loss, has been approximately $30,000 a year, thus indicating a remarkably short retirement period for the initial investment.

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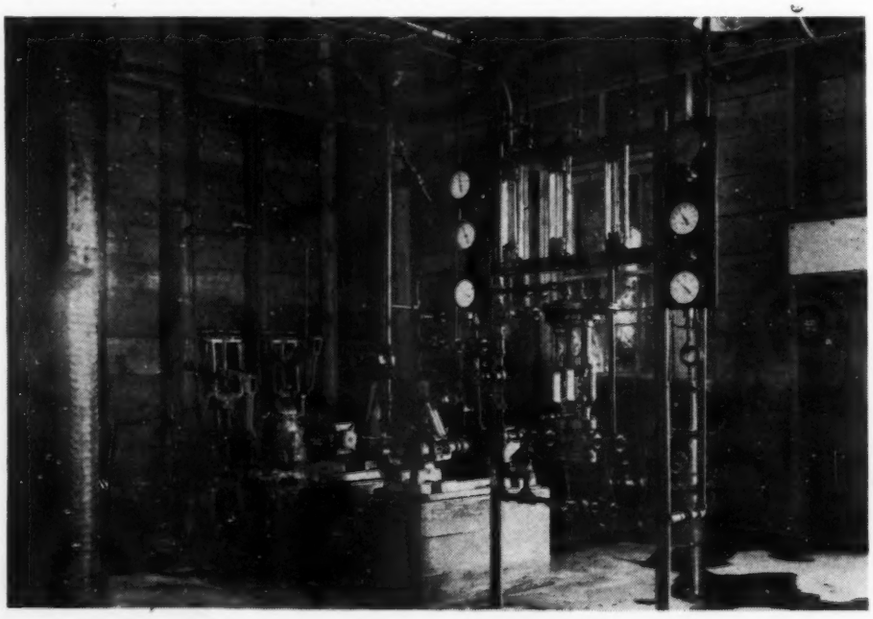
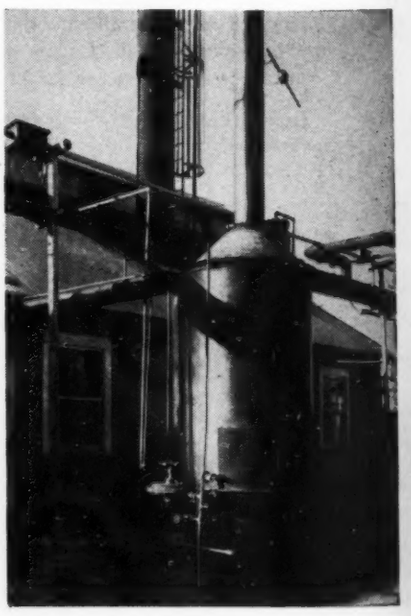
Circulating pump and rotameters



Steam superheater



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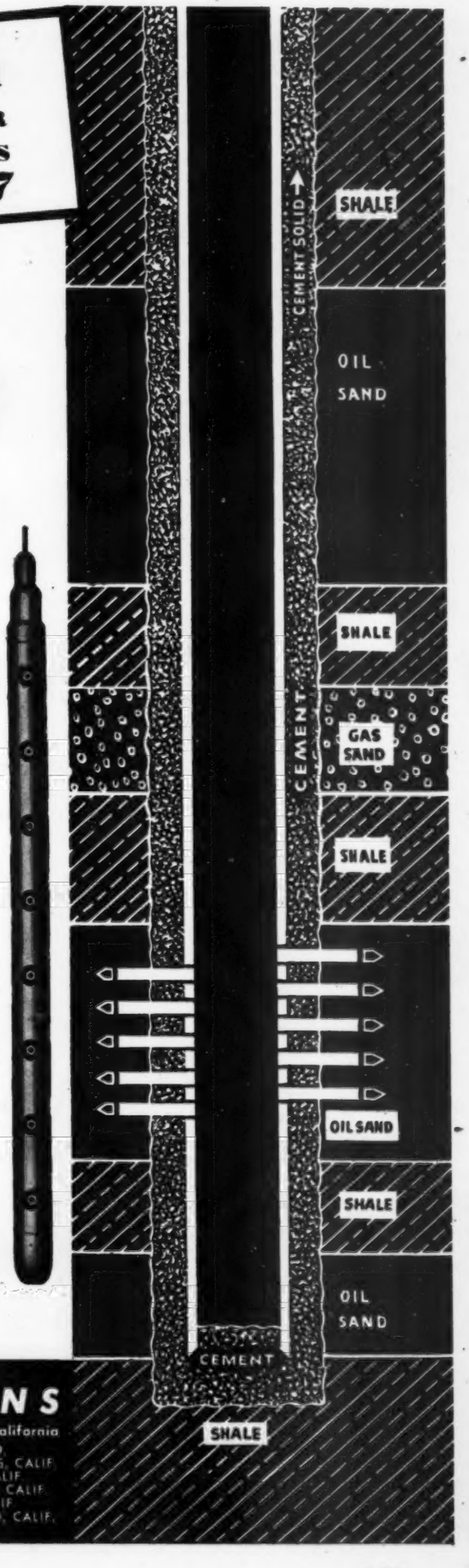

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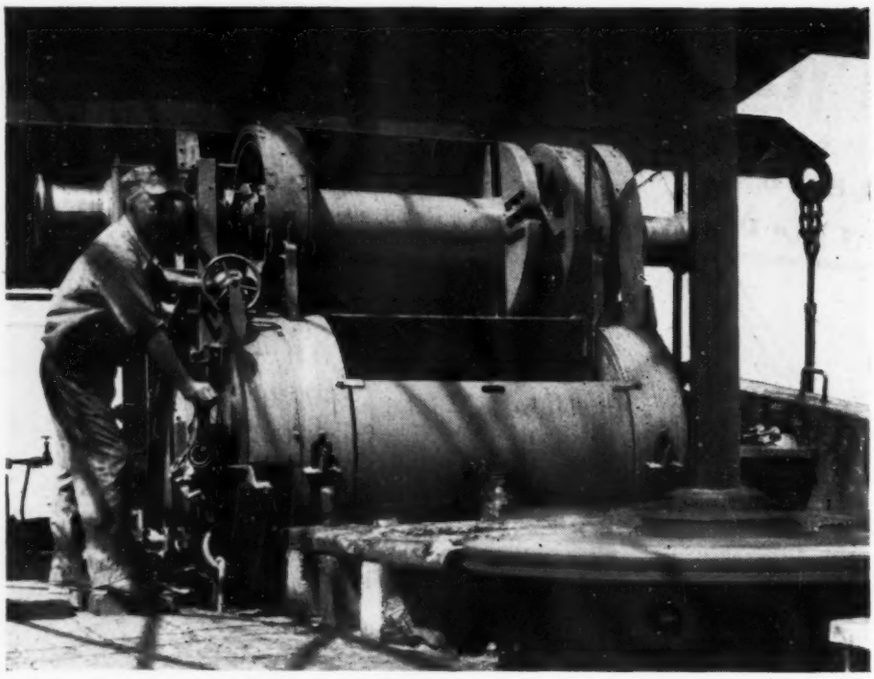

Double drum drawworks for rotary drilling to 5000 ft. with 4½-in. drill pipe. This model can be changed over in the field for cable tool operations by installing a spudding assembly

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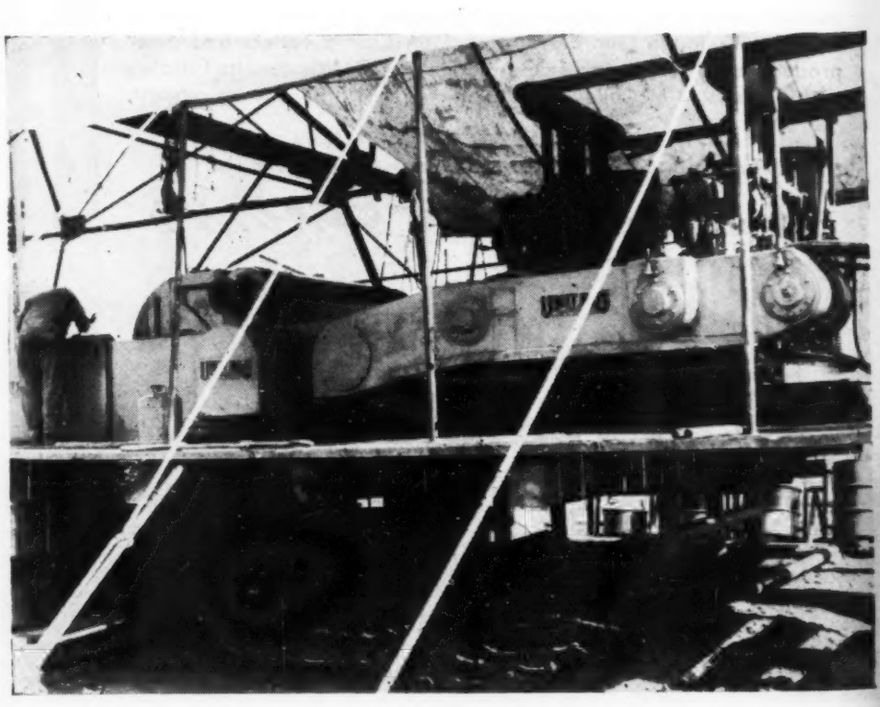
☆ **Light-weight equipment has been particularly useful in meeting war conditions**

by Wallace A. Sawdon

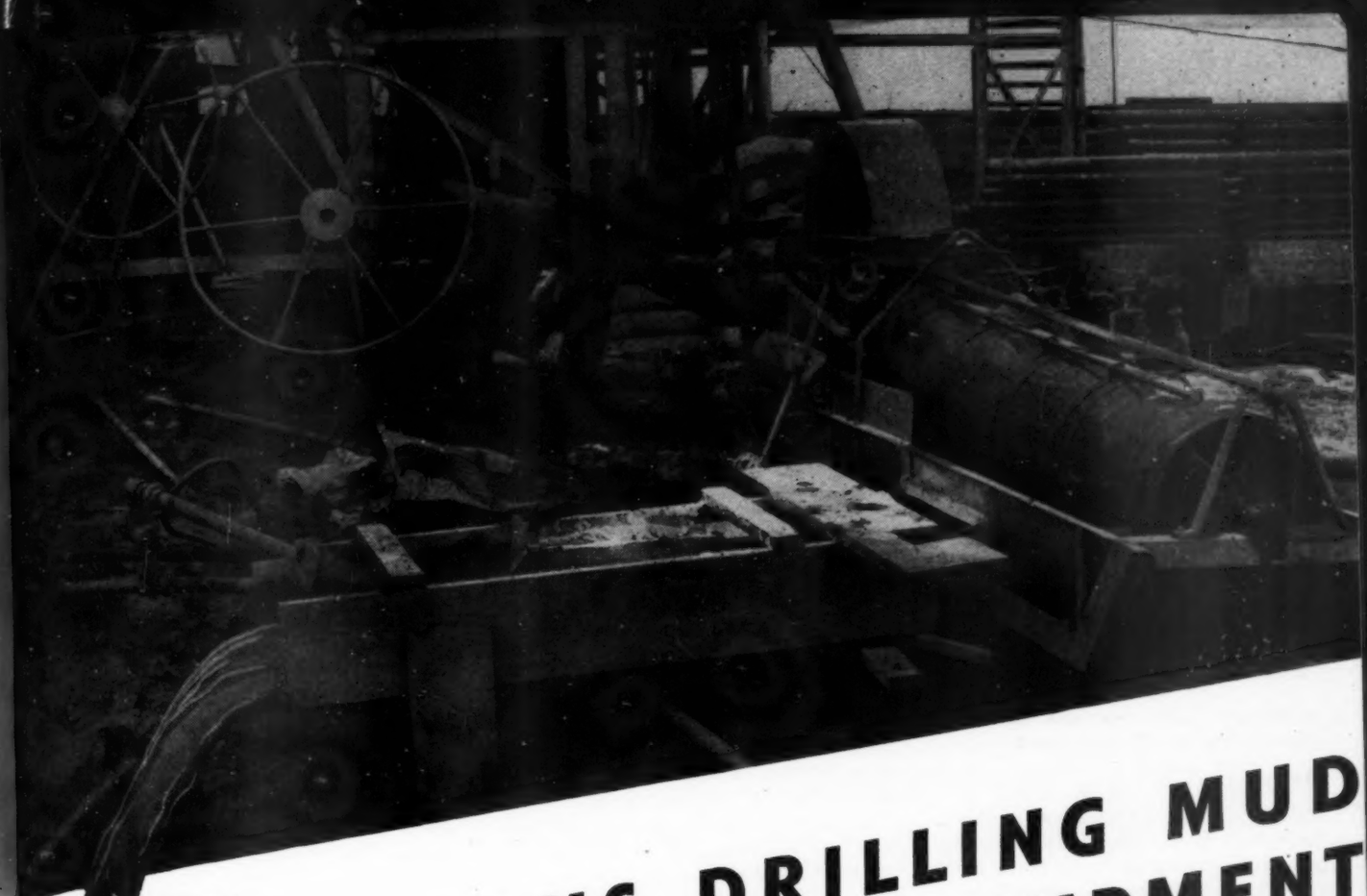
Pacific Coast and Foreign Editor

DEVELOPMENT in design of portable drilling equipment and accelerated utilization of such equipment to help meet war conditions have advanced the acceptance of the portable rig more rapidly than even its most ardent advocates expected. Portable equipment has proved its value under a rather extensive variety of conditions and it is probable that its scope will be increased as portable rig experience is gained and a more specific technique is developed.

Portable equipment has definite limitations, but oil men—the users and makers of equipment and the providers of technical services—have such a happy faculty of overcoming limitations that the adaptability of portable drilling



Rig used to drill 3000 to 7000 ft. when powered by one, two, or three engines with a recommended maximum of 450 hp.



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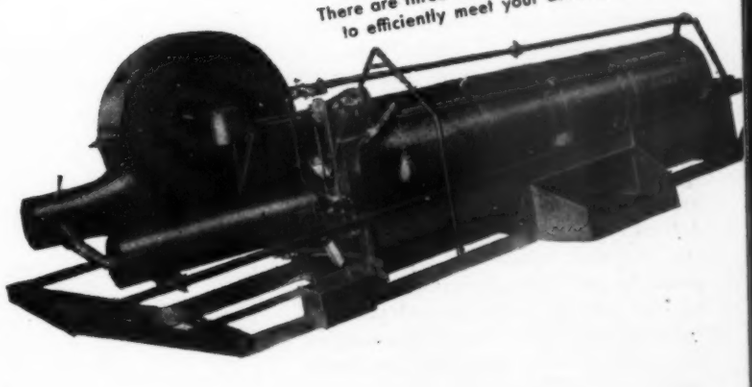

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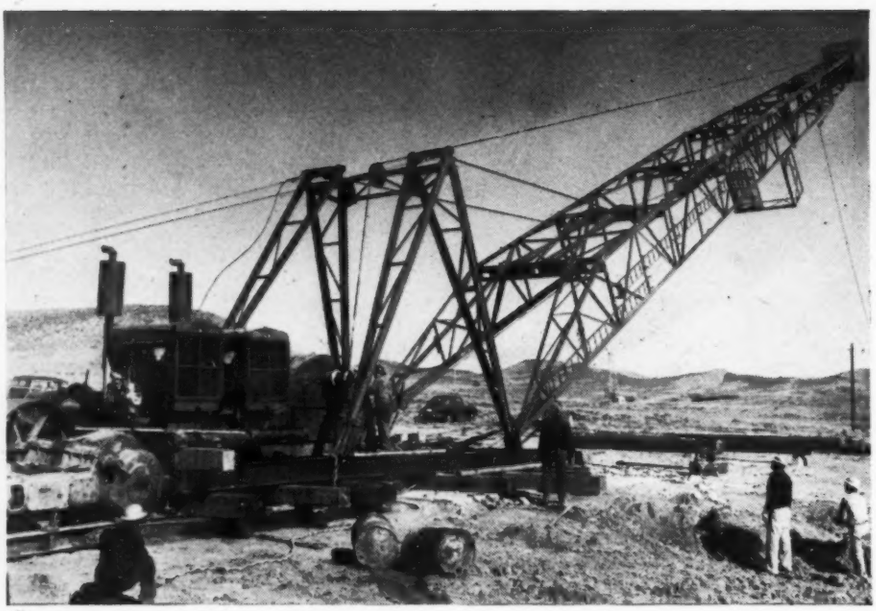


Drilling mast that has been assembled on ground, with crown block in place and lines rigged-up, being raised to working position

equipment may some day be much greater than is at present conceived.

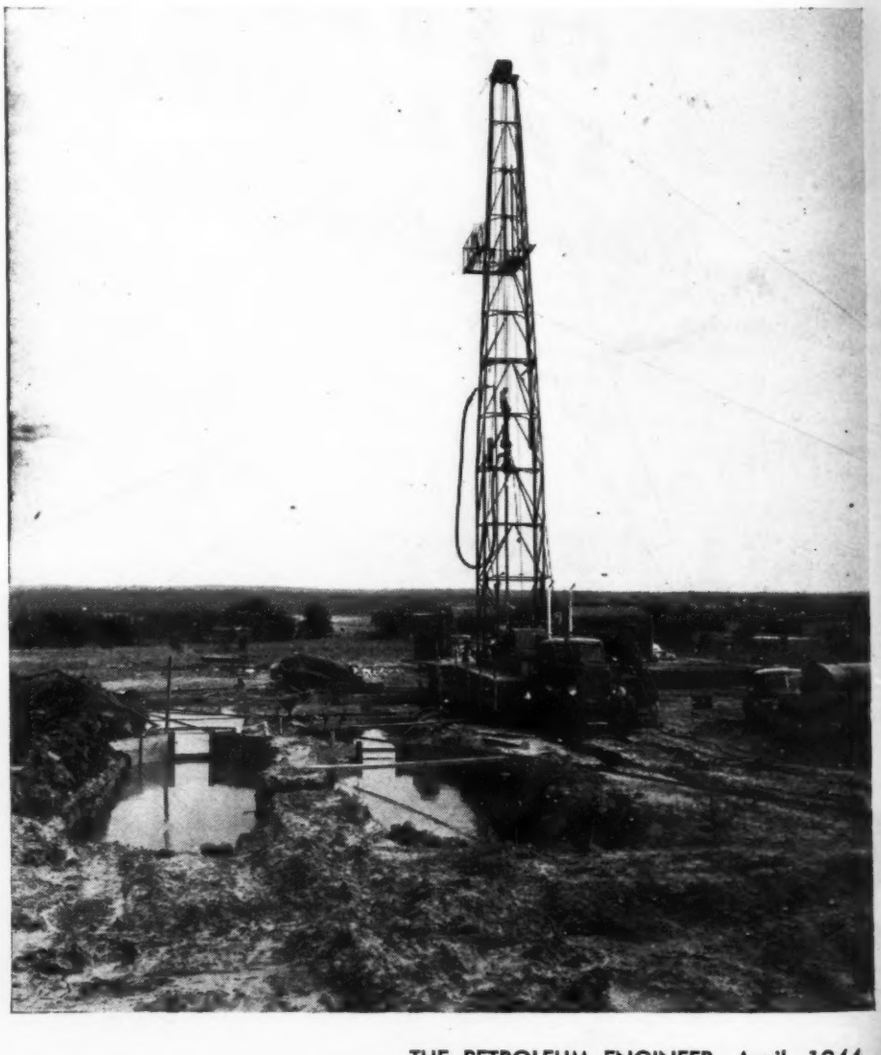
Definition

What is portable equipment? Even heavy rigs are now unitized so that they are readily transportable by truck from place to place. The term cannot be limited to self-propelled units with collapsible derricks or masts because many derricks and masts are permanently mounted with drawworks and engine on trailers or semi-trailers and are practically as portable as self-propelled units. Although limited to operations in one field, some outfits with permanently erected derricks of from 70 to 122 ft. have been mounted on a floor with drawworks and engine and the entire assembly moved on tracks or wheels from location to location. Strictly speaking, portable rigs should include units that are moved up to a permanent derrick set on concrete foundations and the portable equipment then put to work. In fact, power rigs of considerable size are often considered portable because units of the complete assembly are mounted on skids and are easily loaded on and unloaded from trucks for transportation to other locations.

The term "mobile equipment" has been used by some operators to designate any portable drilling rigs that have the derrick or mast, the drawworks and the power for drawworks and rotary table mounted on a vehicle; but some use the term to distinguish between self-propelled and drawn units of this category. The portable drilling equipment herein discussed is any that includes the derrick or mast and is the type to which definite limitations have been ascribed. The derrick and rig may remain on the carrying vehicle while drilling or may be of the skid type and rest on a sub-structure while in operation. As the derrick is part of the unit the derrick is necessarily restricted in size and load capacity and is usually the limiting factor.

In the case of self-propelled units the power through a power take-off is naturally limited by the truck engine but as the power of portable rigs as here considered can be supplied by engines or electric motors provided exclusively for drawworks, rotating operations and raising the derrick, it will be assumed that all power necessary to operate within the capacity of the derrick is available. A great many of the prime movers used to date have been gasoline engines but diesel, natural gas, butane, and electric power have all been employed to some extent.

Although war has accelerated the use of portable drilling rigs it has also, because of shortages in materials and the loss of skilled men, retarded development in design and in portable rig drilling technique. As one manufacturer has



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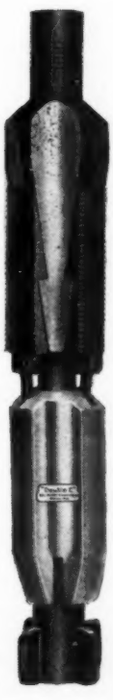

● "DOUBLE E" 2-STEP TUBING CATCHER . . . For wells of average depth. Multiple step design affords greater slip surface — distributes load. With or without anchor.

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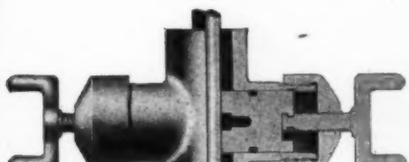
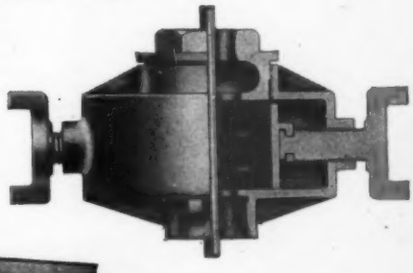
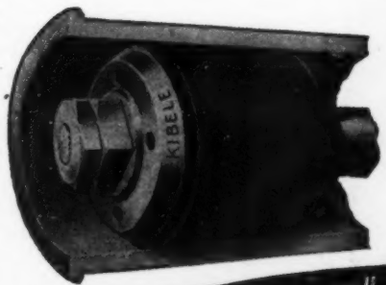


● "DOUBLE E" BLOW-OUT PREVENTER . . . A high pressure safety device designed to stop the heading of wells while pulling rods or running bombs for temperature or pressure on wire lines.



● "DOUBLE E" SUCKER ROD STRIPPER . . . Contains adjustable retractable rubbers which prolongs their life, effects considerable savings; renders highest efficiency.



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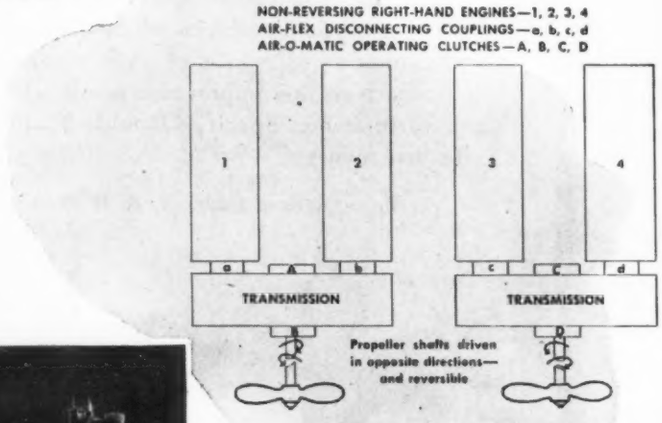

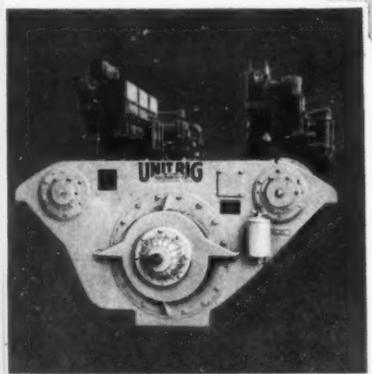

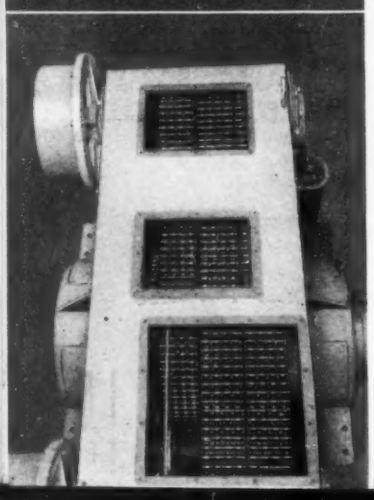

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said, the portable rig business is in a state of "flux," which expresses both the designer's striving for improvement and the operator's endeavor to select the proper equipment for certain depths under more or less uncertain sub-surface stratigraphical conditions. The operator is further handicapped by the manpower situation because men best suited to operate the rigs are not available.

Drilling Depths

The majority of wells drilled with portable derrick drawworks-power units have been shallow holes and the average, due to the preponderance of quickly drilled, shallow wells that were urgently needed during the last year or two, has probably been less than 2000 ft. Wells bottomed at considerably greater depths than this average have been drilled completely with this type portable equipment, the operation including the running and cementing of casing and such other procedures as wall scraping and setting liners.

In one of the deeper San Joaquin Valley fields of California an outfit with telescoping derrick, taking power from a 200-hp. diesel engine through a power take-off, has been used to complete wells at below 8000 ft. In these wells the casing has been landed and cemented before the portable rig was installed but the drilling below the casing was ably handled by the rig, the completion operations being performed with 2⅞-in. O.D., flush I.D. drill pipe.

Equipment Types

The portable derricks and masts are of various designs and include the telescoping and jack-knife types, the raising of the derricks being done by the prime mover or with a separate, small engine provided for the purpose. The lifting operation employs either mechanical or hydraulic action or a combination of both. Load capacities are carefully determined by the manufacturer and these ratings can readily be used to show the adaptability of the derrick for contemplated service.

The suitability of portable equipment to many drilling operations is probably not fully considered by some operators at the present time. Skill in floating in casing, scientific control of the drilling fluid, pressures and volumes of mud pumps, careful selections of bits, proper relationship between rotating speed and weight, and the other details of modern drilling practice are all factors that, when properly utilized, can keep loads off the derrick or prevent contingencies that might overload the capacity of the derrick. The loss of experienced men has probably prevented full realization of the proved drilling practices developed during the last decade and for the sake of safety alone the portable equipment has probably not been used to its maximum limits.

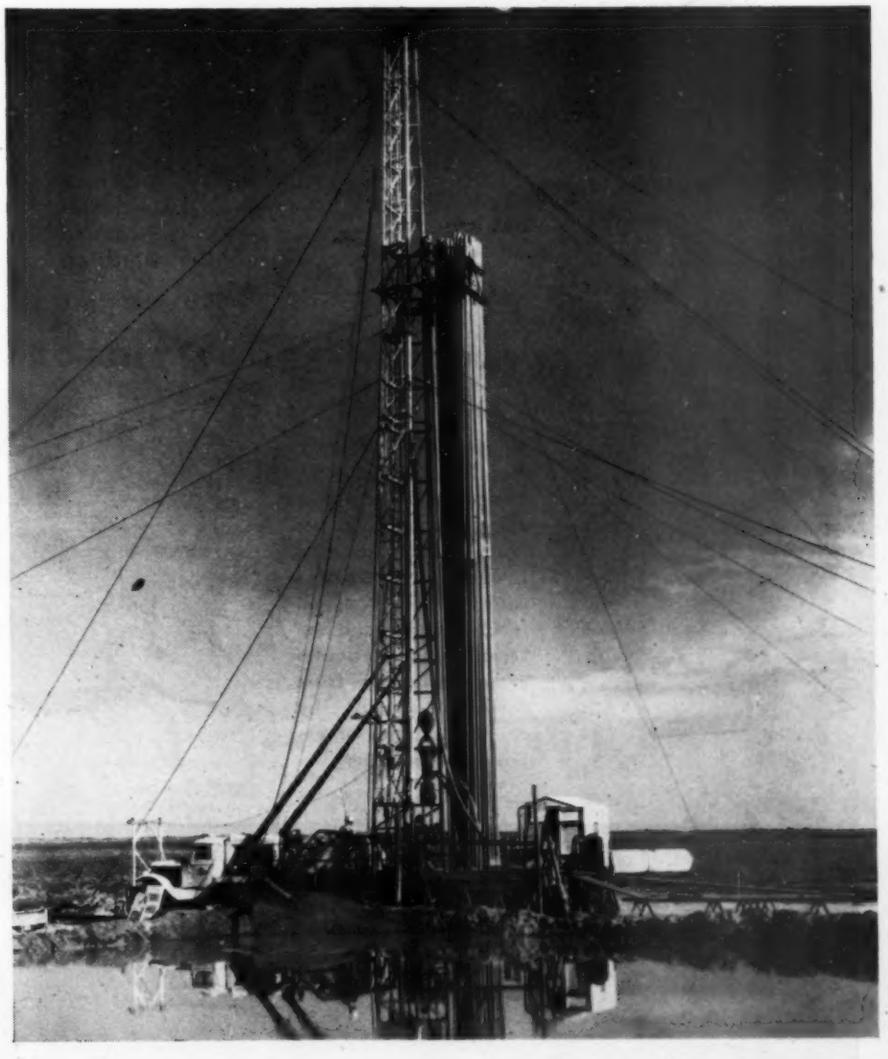
There are so many different types of units being manufactured and assembled that no discussion of the derricks or masts, the drawworks, the prime movers or the ingenuity of assembly is here attempted. Portable rigs have been described and their performance cited in many magazine articles and complete specifications are supplied by manufacturers. The restricted working space in the portable derrick, however, has led to the design of derrick equipment that facilitates operations in the confined area of the derrick, overcoming operating difficulties and reducing danger of injury to the workmen.

The derrick floor can be made larger by the use of extensions but the space within the legs of the portable derrick is not going to be as great as even the 20-ft. base of the smaller standard-type derricks. Actually minimum distances between legs vary with designs but to meet conditions tongs have been designed with short levers for use with the limited floor space. Such tongs, however, will handle pipe ranging in diameter from 2⅜ in. to 8⅝ in. by changing the jaws to fit the pipe in use.

"Streamlined" is a word that has come into widespread use in the American vocabulary. When applied to hooks or connectors and traveling blocks for service in portable derricks the word really has significance. Advanced metallurgy has permitted manufacturers to provide strength with compact design and to eliminate excess material that would not only be detrimental to streamlining but also add to the weight of the equipment itself. Safety features are incorporated in designs and by complete streamlining to eliminate dangerous projections the danger of catching on the derrick braces or on workmen's clothes is eliminated.

In some designs the block is unitized with either a hook, connector or link adapter with bail. The triplex type of hook is provided with one of these

(Continued on Page 162)



A very compact type of portable rig. The hook being used is of the 60-ton triplex type

MOTORS AND CONTROL THAT

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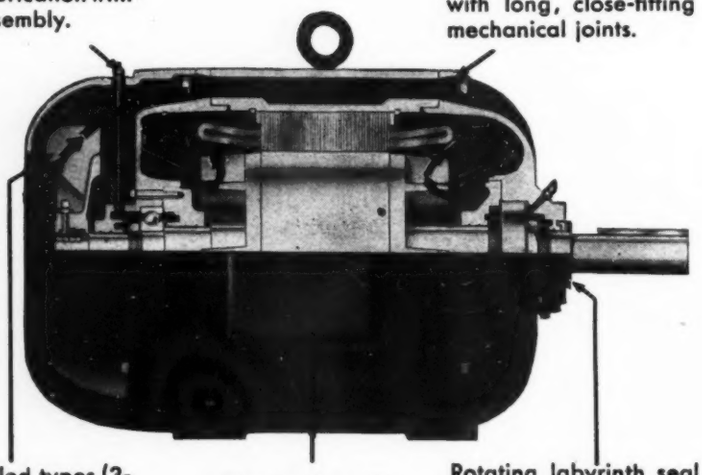
EXPLOSION-PROOF MOTOR CONSTRUCTION

Pressure-relief system permits lubrication without disassembly.

Totally enclosed in a strong cast-iron casing with long, close-fitting mechanical joints.



Fan-cooled types (3-hp up) effectively cooled by air forced through the double-walled stator frame.

Diagonally split cast-iron conduit box is explosion-proof.

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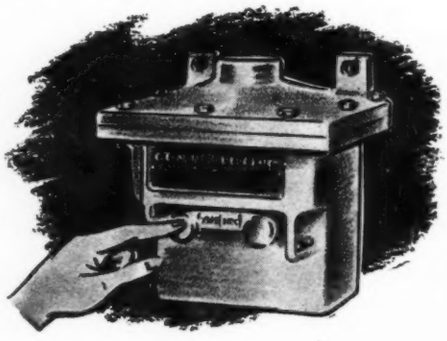
EXPLOSION-PROOF MOTOR CONTROLS

Combination starter for Class I, Group D, locations. All contacts are at least 6 inches under oil. Easy-to-read indicator provides safety check on oil level. Extra-tough exterior finish provides extra protection from corrosion caused by chemical fumes or exposure to weather.



Push-button station for corrosive and hazardous-gas locations. All contacts operate under oil. Entire unit is enclosed in cast-iron case specially finished to withstand acid fumes, alkali dust, or outdoor service.

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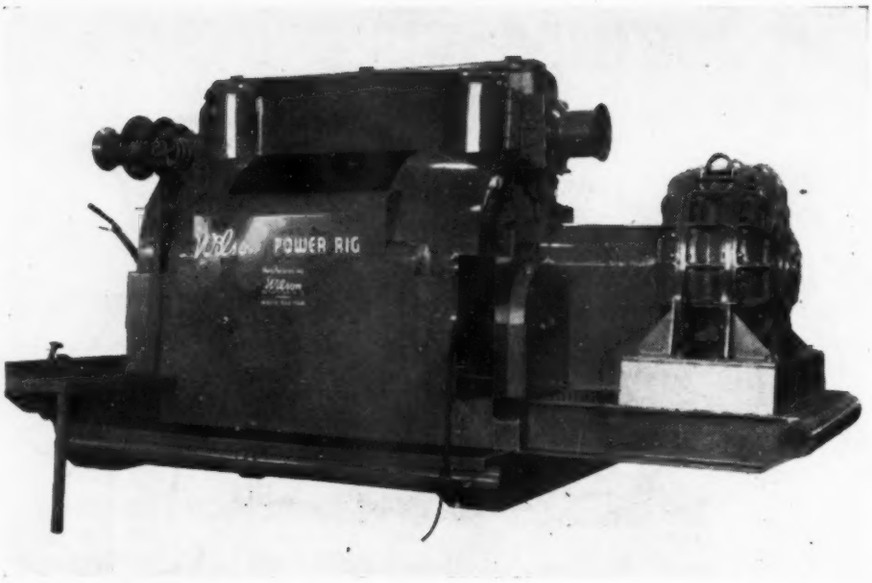
MOTORS AND CONTROL

for Hazardous Areas



One type of drawworks used extensively on portable drilling rigs

(Continued from Page 159)

block-hook units and the single hook with others. Separate hooks are preferred by some operators and various makes are being supplied that are adaptable to portable derrick operation.

Crown Block Design

Crown blocks are of various designs, some being made integrally with the derrick or mast. A recent development is designed to provide simple over-and-over reaving of the drilling line to eliminate cross-over of the lines and insure traveling of the block in a straight line without drift or fleet angle. The sheaves are mounted in line so that all drilling lines are parallel and in the same plane as they feed to and from the block. This feature prevents twisting and drifting of the traveling block and eliminates pull-back from the center of the hole, permitting the block to travel in a vertical line without risk of striking the bracing of the derrick or the finger board.

This particular design is made in two types, one for use where the fast line comes down inside the derrick and the other where it comes down to the drawworks outside the derrick. In the latter type the fast line sheave is of a larger diameter than the other sheaves and is mounted eccentrically with respect to the bearing shaft of the other sheaves. The groove of the large sheave is in line with the grooves of the other sheaves on the inside of the derrick but extends beyond on the other side to clear completely the outside of the derrick. The fast line thus operates on a larger sheave than the other lines and reduces the speed of rotation of the fastest sheave.

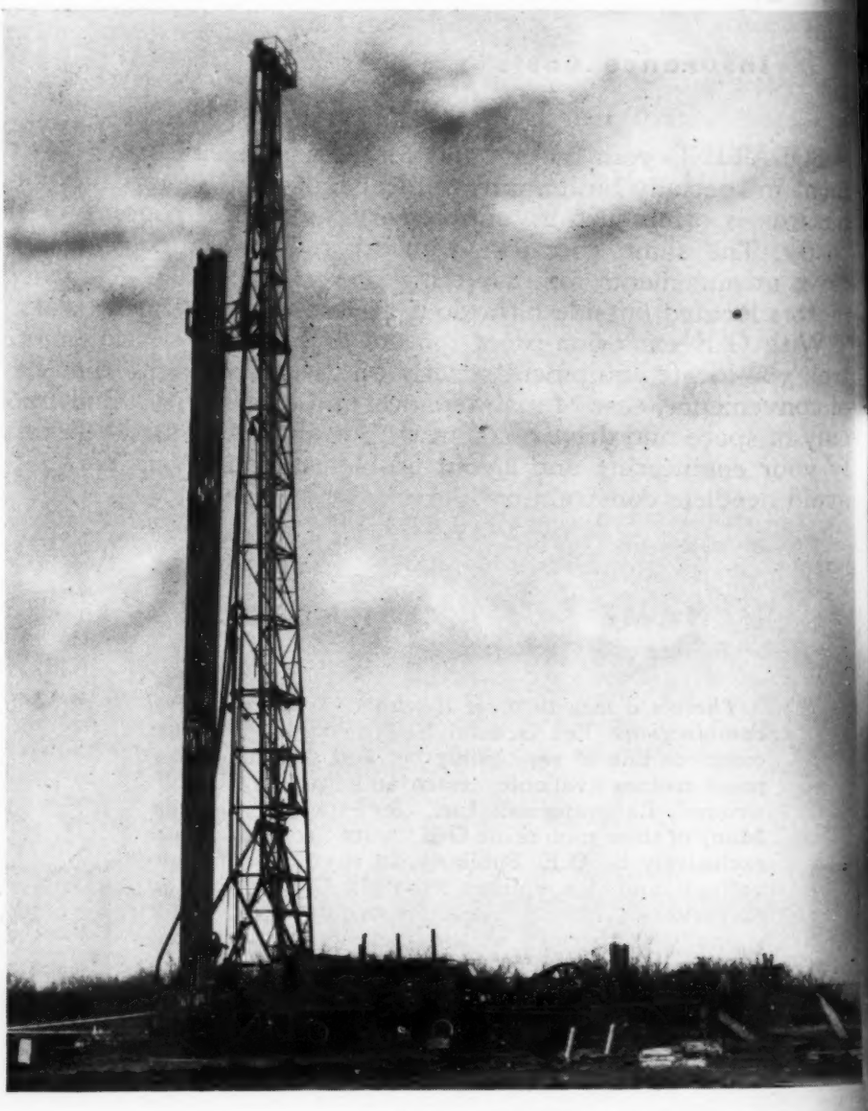
Some equipment, such as rotary hose, is permanently mounted in the portable derrick. Swivels are, of course, of size to fit the rig and special light swivels with short bails have been designed for use with portable rigs. Due consideration must, of course, be given to fluid passage, which must be adequate for the operation and drilling methods contemplated.

A recent design of swivel bail adapter provides an elevator connection on the swivel for supporting the swivel and drill string with the same links and elevator with which the drill pipe is handled. This adapter consists essentially of a saddle and clamp arrangement that fastens to the swivel bail and a vertical body section around which the elevators lock. When installed it becomes virtually a rigid portion of the bail itself.

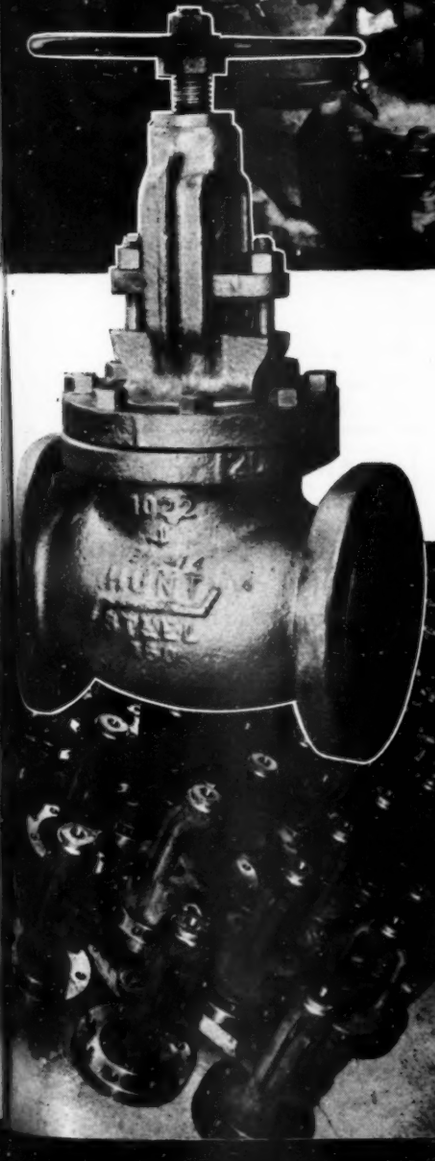
Power pumps for drilling-fluid circulation are readily transportable as separate units and any pump capacity necessary for the particular operation can be provided.

Rotary Table

The rotary table is sometimes a part



Drilling mast in operation. Note that the legs on the gin pole can be adjusted to accommodate any standard unitized drawworks, power and rotary



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HUNT TOOL COMPANY

of the drilling unit (as in the case of some self-propelled outfits) and is then designed to coordinate with the rest of the drive mechanism. Most types of portable rigs, however, employ special small tables that are now being supplied to facilitate operations on the confined floor of the portable derrick. For example, there is the 12½-in. light-weight machine made with 36-in. spacing between the sprocket and table center. These small tables accommodate the drill pipe now being used with the portable equipment, as this drill pipe is seldom of diameter greater than 4½ in. Table speeds up to 250 or 300 r.p.m. are practicable with many designs.

Special drill pipe slips are available in the 4½-in. size to fit such tables. One design of such slips have replaceable liners to accommodate sizes from 4½-in. drill pipe down to 2-in. tubing in the same bodies. Special drill collar slips are also made to fit the small tables. One type is made with multi-segment body that wraps around the collar like a chain tong and compensates for wear. Roller kelly bushings are manufactured with special square to fit the small tables.

Portable outfits that include derricks with the rig units mounted on one vehicle have been used to drill wells to depths below 5000 ft. and one or two wells were reported to have been drilled and completed at depths of 6000 to 7000 ft. with this type of equipment. Due consideration must be taken of the kind of drilling to be done because all formations do not lend themselves to the so-called slim-hole operations that such depth would suggest. Troublesome formations must be expected in some areas and, although experience in drilling such formations may add considerably to the possible depth to which the well can be drilled with a rig of certain capacity, experienced men are hard to find at the present time.

It might not appear to be economical to purchase a large capacity portable rig for the drilling of very shallow wells, but a portable rig is portable and is really transported to other areas where it may be desirable to use it for drilling wells of greater depth than those immediately scheduled. A larger rig will drill shallow wells but a small one cannot be used beyond its capacity.

Exploratory Drilling

The adaptability of the completely portable rig and mast for exploratory drilling has been recognized by some operators. One company in California is now using a large rig of this type to drill test wells and intends to drill to 10,000 ft. or more if necessary. Special drill pipe is to be used for the deeper drilling, this pipe being 4½ in., 13 lb. to provide light-weight and larger circulation passage. It is not the intention at present to run long strings of casing into these wells but upon discovery of oil to drill other wells for production. The exploratory wells will provide means of obtaining stratigraphical data that can also be used in subsequent drilling and for geological purposes.

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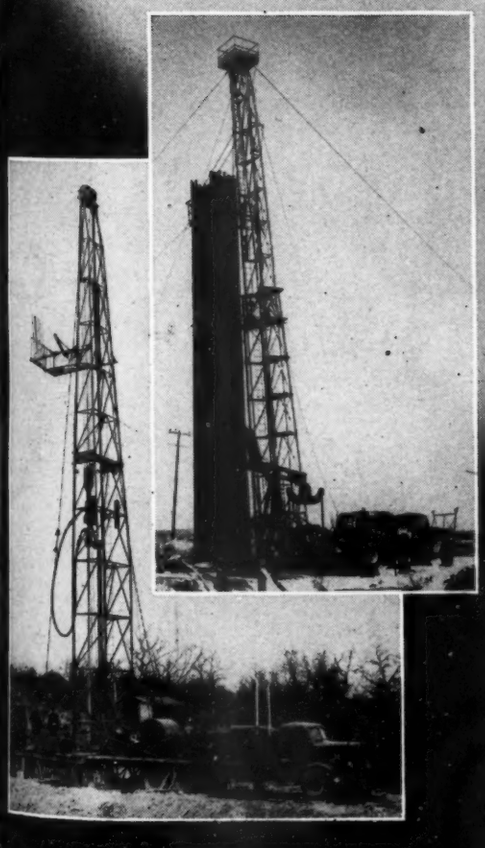

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by R. O. Walton
Engineer, Merla Tool Company

A UNIT gas lift installation*, has been developed and is now being used extensively in many different areas. The new method and equipment is applicable to both high and low bottomhole pressure wells; and is equally applicable to wells having either high or low productivity. This installation consists of a time-operated pressure surface controller and responding pilot-actuated subsurface valves.

The system, employing the pilot-actuated valves and surface controller, is unusual in that it is adaptable to any well, regardless of depth or type, if fluid is to be lifted and gas under pressure can be made available.

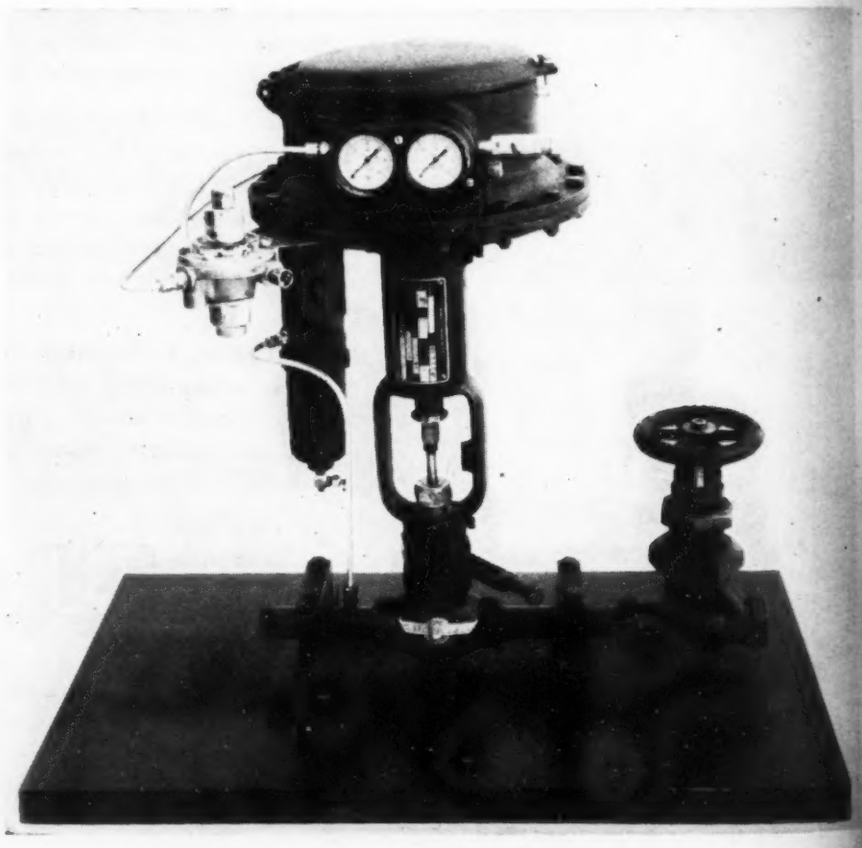
Operation of the surface controller is familiar to operators experienced in gas injection. The surface unit is a rugged time-actuated motor valve in conjunction with an adjustable mechanical-volume control valve. By slight adjustments on the time control wheel, any frequency of on-and-off periods may be selected. After these adjustments are made additional control is available by use of the volume control valve.

The subsurface pilot-actuated valves are mounted on 3-ft. tubing subs, having full tubing openings through them. Their pilot valves are set for predetermined operating pressures before being run in a well. The construction of the valves is such that each valve will pass any volume of gas admitted to the casing annulus, after the casing pressure reaches the operating pressure of that particular valve. For example, if the pilot of one of the valves is set for an operating pressure of 300 lb., the valve will remain closed until the casing pressure increases to 300 lb.; at that point the valve will open. If the controller is set to inject gas at the rate of 10,000 cu. ft. per hr., the subsurface valve will pass gas from the casing annulus into the tubing at that same rate until the surface controller closes and allows the pressure to return to 300 lb., in turn closing the valve. The casing pressure will then remain at 300 lb. until the surface control valve opens for the next cycle of operation.

Where more than one valve is needed to unload a well from its static fluid level down to a working fluid level, the valves are set in the well so that the highest pressure valve is at the top of the string and each successively lower valve is set with a slightly lower operating pressure. Thus the valve having the lowest operating pressure is situated at the bottom of the string. This is done: First, to maintain the casing pressure lower than the operating pressures of the upper exposed valves and will keep them closed; second, the lower valves under fluid will remain open and allow fluid to bypass from the casing annulus into the tubing. After an installation of this kind is made, the gas is injected and the casing pressure is allowed to reach the operating pressure of the top valve. At this point the desired frequency of operation is set on the surface controller and the well will produce down to its proper working fluid level without additional attention. This feature of automatic work down in a well that is logged up will save many man hours to the operator.

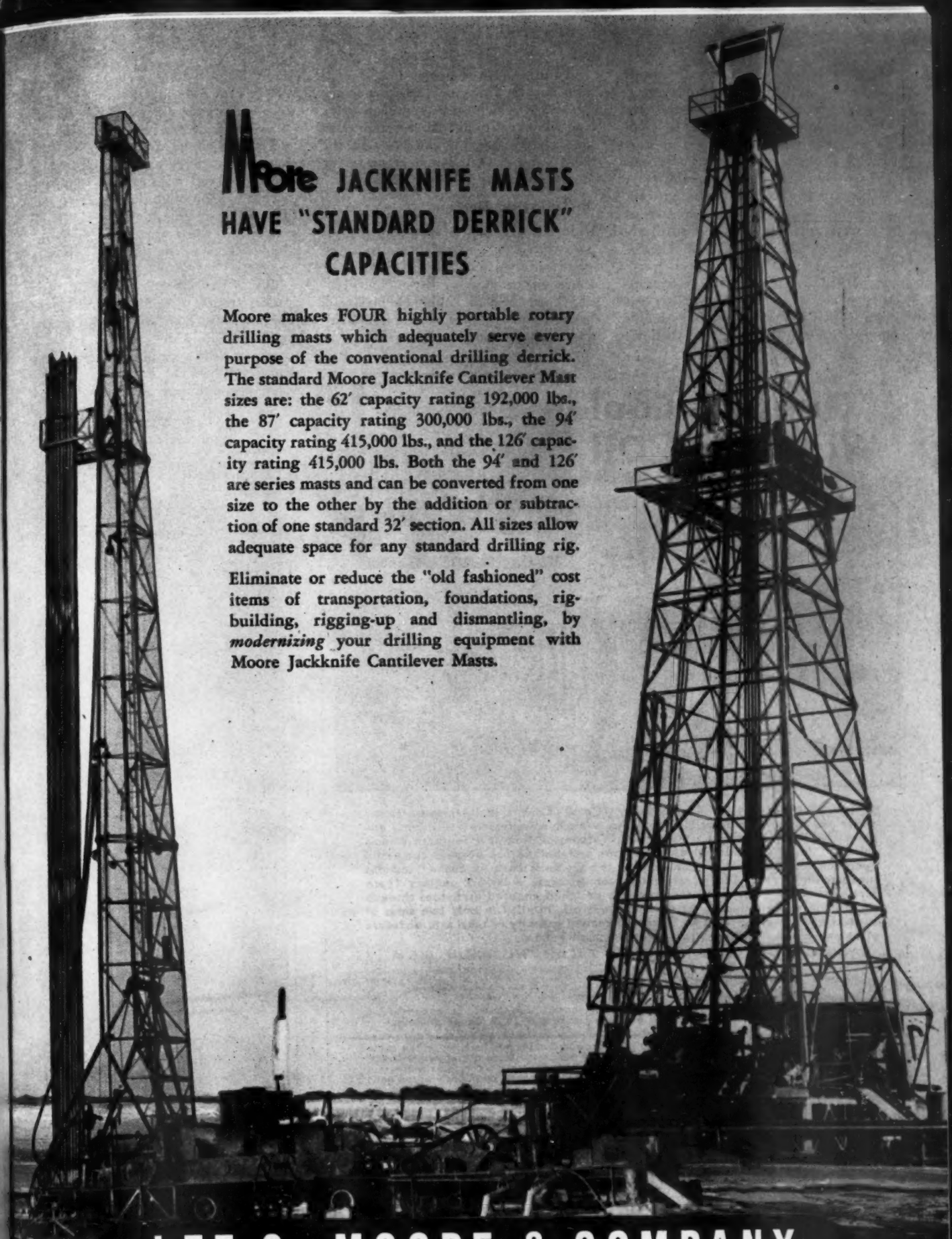
Description of Valve

Fig. 1 shows a sectional view of the pilot-actuated valve. The pilot bellows is sealed to the pilot chamber, sealing in atmospheric pressure that will remain constant regardless of well pressures. This atmospheric pressure chamber makes it possible to set the pilot valve at any predetermined pressure and maintain that same operating pressure regardless of varying well pressures. The pilot tension spring is set with the pressure adjusting nuts to extend the pilot bellows and hold the pilot valve on its seat, thereby preventing gas passage into the power bellows. Pressure is communicated through the pilot ports to



Surface controller

*By Merla Tool Company.



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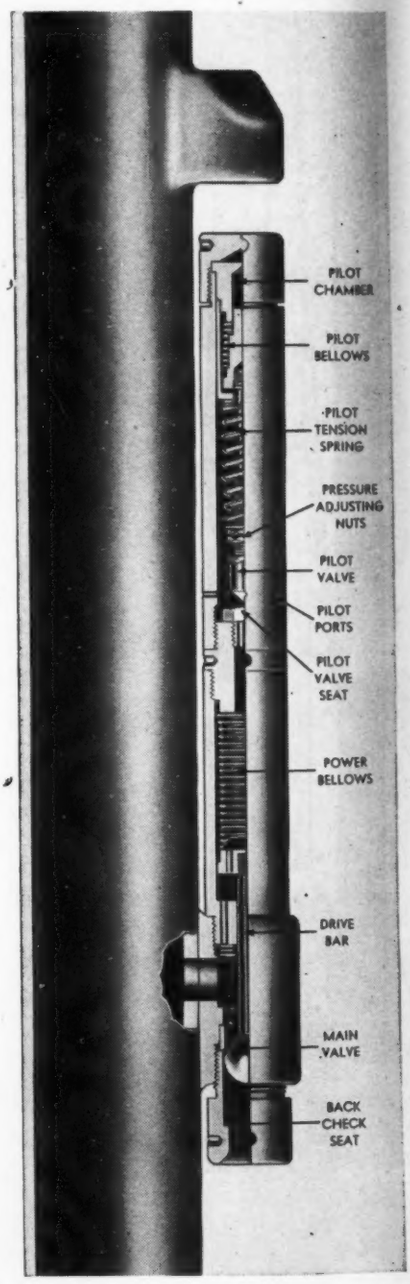
the pilot bellows. This pressure acting on the area of the bellows tends to overcome the tension of the spring and raise the pilot valve from its seat. It is apparent that when the casing pressure reaches a point sufficient to overcome the tension of the spring the pilot valve will open and allow gas to pass into the power bellows. The bellows consists of a flexible chamber having a small restricting port at its lower end. The capacity of the pilot valve is much greater than the capacity of the restricting port in the power bellows so that gas passing through the pilot valve builds up pressure within the power bellows and causes it to elongate. This elongation imparts a downward thrust to the drive bar, which opens the main valve and allows gas to flow from the annulus into the tubing. As can be seen, the pilot valve is the all important factor in the operation of the valve.

Installation Designs

Installation designs may be placed in two different general forms to meet practically all well conditions. Fig. 2 shows an installation that includes the conventional well tubing, a hookwall packer, and the subsurface pilot-actuated valves. This type installation is easily adapted to all wells except those of the extremely low bottom-hole pressure or stripper type. The packer confines the high pressure gas to the annular area above the pack-off so that when the valves are closed the fluid from the well bore can feed into the open tubing through the standing valve. This fluid expands above the operating valve and when the valve opens the fluid is raised to the surface by the lifting gas.

Fig. 3 demonstrates the use of a subpacker volume chamber arrangement in conjunction with a dip tube. In this installation, as in the above, the gas is confined to the annular area above the packer. When the lower intermitting valve opens this gas is admitted on top

Fig. 1. Sectional view of pilot-operated valve



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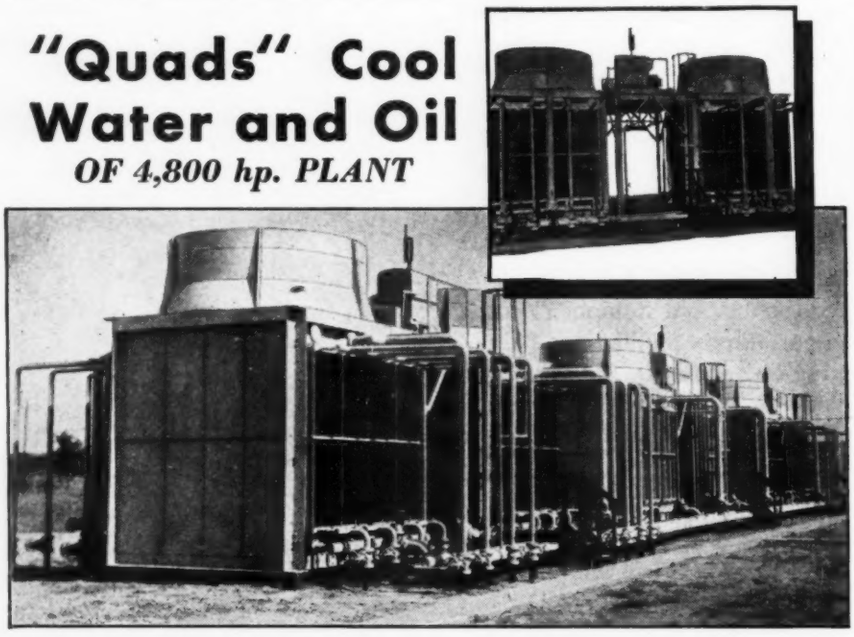

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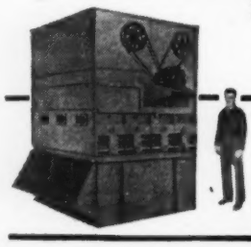
*Three "Quad" Condensers are used to condense 40,000 lbs. of steam per hour at 10 lb. gauge pressure.



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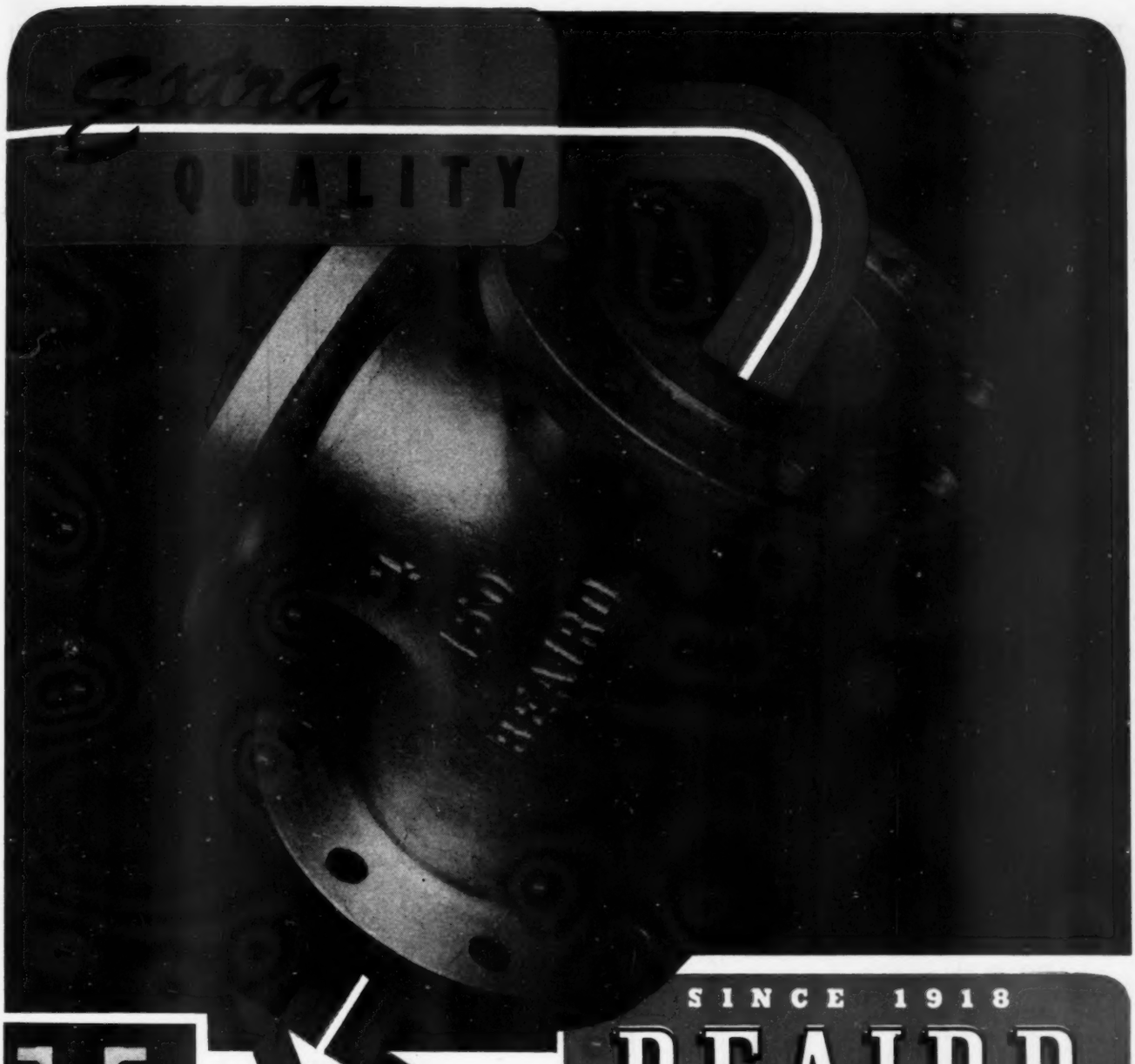

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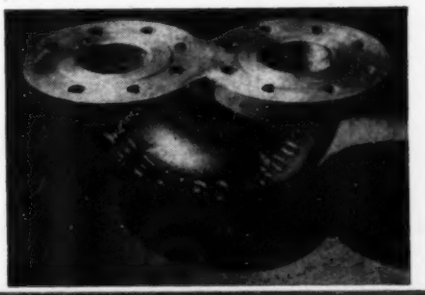

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of the fluid in the volume chamber thereby forcing the fluid up the dip tube and into the tubing, the gas then follows under the fluid forcing it to the surface.

Spacing Factors

Primary factors controlling the proper spacing of these valves in a well area are as follows: (1) Gas pressure available for operation; (2) static bottom hole pressure, and (3) gradient of well fluid in pounds per square inch per foot height. The productivity of the well is another desirable factor, but in most cases this is not available so the following calculations for valve spacings will not include productivity except in a general way.

Experience has shown that for the purpose of calculating valve spacings, all wells requiring artificial lift may be divided into two general classifications: (1) Wells having static fluid levels relatively near the surface and (2) wells having fluid levels far from the surface. To determine the classification of a particular well, the procedure should be as follows: (a) Find the fluid level from the surface by use of the formula below, and (b) calculate the height of the column of fluid the available gas pressure will support by the accompanying formula:

$$FL = D - \frac{BHP}{G} C = \frac{P_g}{G}$$

Where:

FL = fluid level from surface,
BHP = bottom hole pressure,
G = gradient of well fluid in lb. per sq. in. per ft. ht.
C = height of column of fluid gas pressure will support,
P_g = gas pressure available for operation, and
D = depth of well.

If C is greater than FL the well belongs in class (1), but if FL is greater than C, the well will be in class (2).

To locate the distance the top valve should be from the surface, use formula (1) for class one wells and formula (2) for class two wells:

$$S = \frac{P_g}{G} \quad . \; 1 \qquad S = FL + \frac{P_g}{PxG} \quad . \; 2$$

Where:

S = distance from surface to top valve, and
R = ratio of annulus volume to tubing volume.

After the top valve setting has been located, the subsequent valves should be spaced according to the following formula:

$$S_v = 0.80 \frac{P_v}{G}$$

Where:

P_v = operating pressure of each subsequent valve, and
S_v = spacing between valves

If the productivity of the wells is

Fig. 2

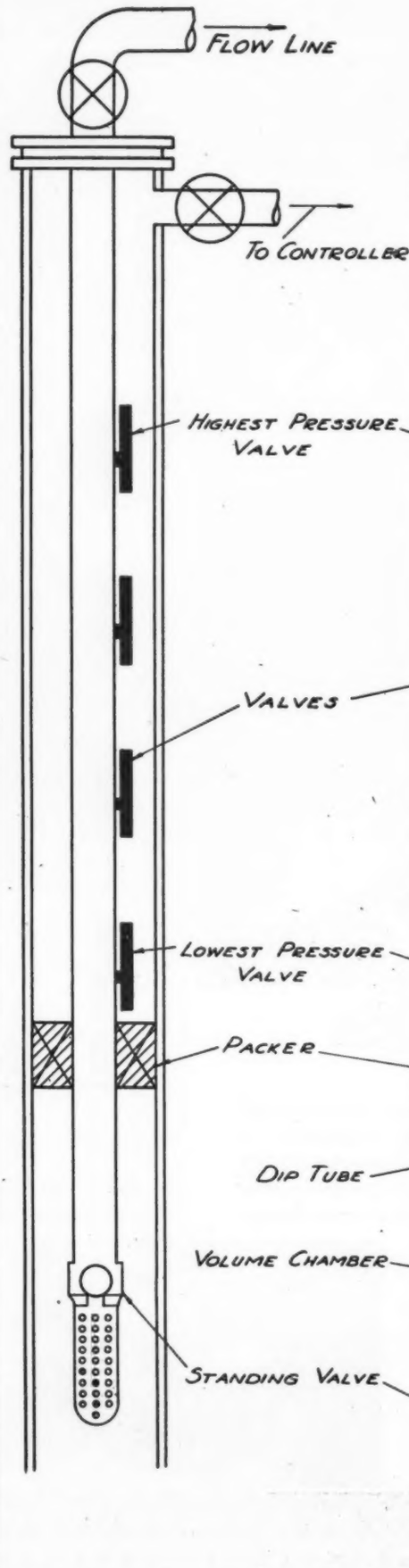
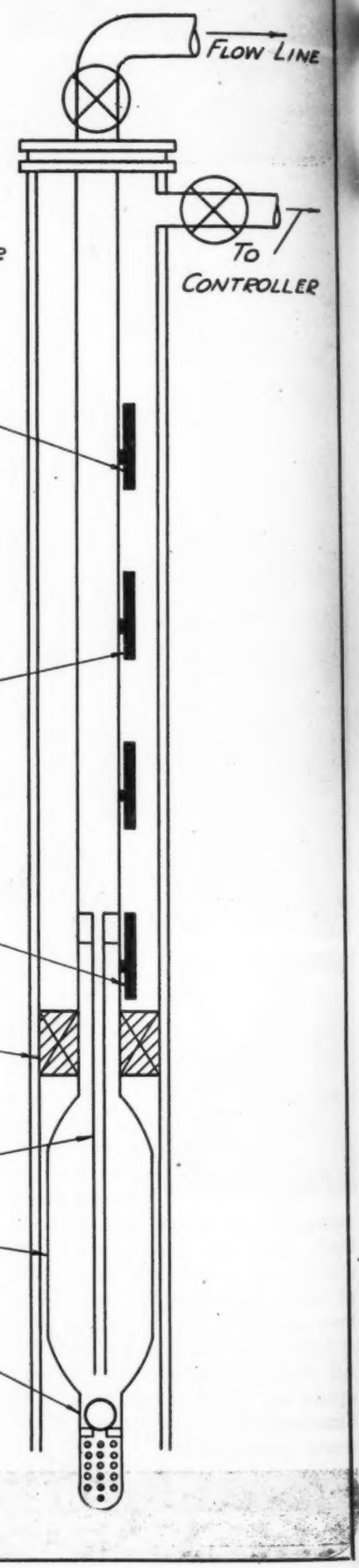


Fig. 3



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known to be high, and large volumes of fluid are required then subsequent valve spacings, as calculated from the above formula, should be reduced 25 per cent.

The calculation of the valve settings herein described are applicable to all types of wells, which include the two installation types shown.

Successful operation with the pilot-actuated valve and controller combination has been observed in many different areas and in virtually all types of wells. Two cases of operations are given below.

In the Shreveport, Louisiana, field several of these installations are producing fluid from a depth of 5600 ft. with a valve operation of 250 lb. These wells have an average bottom-hole pressure of 300 lb. and are producing 42 gravity oil in addition to water percentages up to 20 per cent. The average fluid lifted per day is 100 bbl. and the controllers are set to inject gas 3 min. out of each 30-min. period, thus causing the well to make a complete head of fluid every 30 min. The installations are all working from the bottom valve in the string. These installations would be capable of handling much larger volumes of fluid through the 2-in. tubing if the wells had the capacity. The 250-lb. valve operating pressures are not universally recommended for wells of this depth, but such operations are an indication of what can be accomplished even with extremely low pressures, when modern intermitting equipment is used.

Central West Texas has many wells that have given considerable trouble to various forms of lifting equipment. Many of these wells are small producers and yield varying quantities of sand. Installations with the pressure-controlled pilot feature, in conjunction with the sub-packer volume chamber, have been employed in this area and are producing the wells very satisfactorily. One installation of this type producing from 2200 ft. is lifting all the fluid the well is capable of producing, 6 bbl. of 36 gravity oil per day, with considerable sand. This well is set to intermit one head of fluid every 6 hr. and has a gas-injection time of 1½ min. every 6 hr. Even though wells like this one are extremely hard on most types of equipment, this installation gets the production every day.

P 625.4

Repair of Gas Line Under Pressure*

by John Novak

E. I. Du Pont de Nemours & Co.

A RUPTURE in a 12-in. steel gas line in which a non-combustible gas is handled at approximately 5-lb. pressure presented a difficult repair problem because the rupture occurred at a most inopportune time—a time when a shutdown was quite undesirable and exceedingly costly.

At a point where the 12-in. pipe joined a standard 12-in. by 19-in. forged flange, a crack approximately 6 in. long and ⅛ in. wide developed.

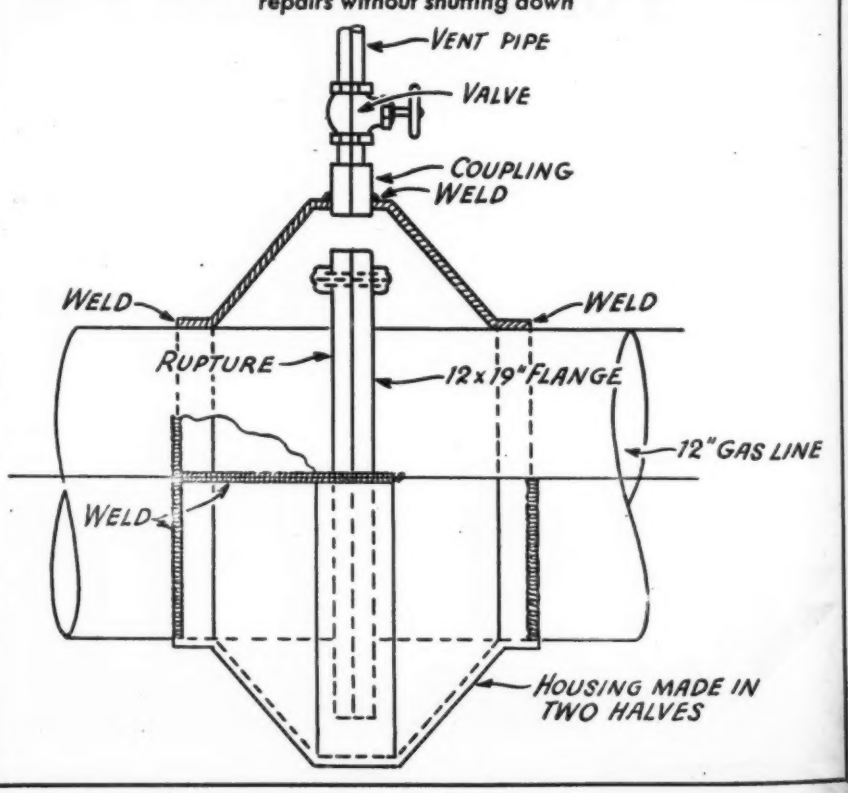
After some thought it was decided to repair the leak without shutting down.

A split housing having sufficient depth to clear the flange but still fit snugly around the 12-in. pipe, as shown in the accompanying sketch, was fabricated from No. 10 gauge sheet iron. A 2-in. coupling was welded in a hole in one half of the housing and a 2-in. closed nipple and valve screwed into the coupling. The two halves of the housing were securely clamped over the 12-in. pipe and flange at the point of failure. A 2-in. pipe line connected to the 2-in. valve in the housing carried much of the leaking gas away from the area, thus clearing the atmosphere and relieving the pressure in the housing, all of which improved welding conditions. After welding the two halves of the housing together and securely welding the housing to the 12-in. pipe, the leak was under control. The 2-in. valve was then closed and the 2-in. line beyond the valve dismantled.

The repairs resulted in a saving of more than 1100 per cent. The repairs cost approximately $120, whereas a shutdown and resulting loss of production would have cost approximately $1500.

☆ ☆ ☆

Sketch showing housing welded over ruptured pipe and flange to effect repairs without shutting down



*From a paper submitted in the Industrial Progress Award Program sponsored by The James F. Lincoln Arc Welding Foundation, Cleveland, Ohio.

Photographed at S S C's Party Chief and Supervisor Meeting December 26th-28th, 1943

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P 094.84

Let's Be Realistic About the Gas Turbine

by F. T. Hague

Manager, Steam Engineering,
Westinghouse Electric and Manufacturing Company

ONE might well ask "Why the sudden popular interest in the gas turbine power plant?"

There are several considerations that combine to supply a common answer. A new form of aircraft propulsion turbine has been dramatically publicized; the current availability of high temperature alloys has made it possible to build gas turbines for this application having intriguing characteristics; the efficiency possibilities of gas turbines have been high pressured by theoretical dreams of possibilities of academic writers. This situation touched off the spark that caused imaginations to "run wild" and predictions to be made rather indiscriminately about the gas turbine power plants' revolutionary future.

Everyone wants an evaluation of the future possibilities of new developments before they are reduced to practice, and such evaluations can rarely be made accurately. We have learned to discount the high pressure optimism with which practically all new developments, regardless of their merits, are presented to the public. We can approach the gas turbine plant realistically by noting that up to the present time commercial installations in this country have been limited to low temperature units in refineries where the combusted gas supplied the gas turbine as a by-product of the refinery operation. These are not installations for the generation of primary power. There are excellent reasons why commercial power installations have not previously been made.

The component parts necessary for high performance operation have not previously been available and are only now in the initial stages of development. High performance of simple gas turbine plants requires very high operating temperatures with attendant short life. High performance of complex gas turbine plants at low temperatures to insure long life requires the availability of the best in metals, the most efficient types of aerodynamic structures, the development of efficient intercoolers, reheaters, and heat exchangers, together with the efficient combustion of the lowest grades of liquid fuel.

Newest Form Power Generation

The gas turbine power plant is the newest form of power generation. It is probably understood that any new form of power generation can be expected to have both desirable and undesirable characteristics just as the older forms are recognized to have. In those applications where the existing forms are under handicaps of size, speed, or efficiency, etc., it is possible that the new form may show its more favorable characteristics and find a real and useful field of application. Under no circumstances can the gas turbine power plant be looked upon as superseding present forms of power generation. Perhaps it will supersede some types in specific applications, but it will most certainly supplement many types in many applications.

High Speed Machine

The gas turbine is a very high speed machine. Where high speed or geared units are usable, definite gains in size, weight, and other characteristics may be very attractive. The theoretical possibilities in efficiency of the gas turbine cycle is currently being overemphasized as the principal characteristics of its desirability. It would be much more realistic to admit that only the integration of all its characteristics will determine its ultimate status.

Where existing types of power generation are not doing too good a job in some respects the gas turbine plan may be a potential competitor. Smaller steam plants under 5000 kw. begin to become high in unit cost and lower in efficiency than the larger central station units. The gas turbine plant characteristics are much more favorable in these respects. In contrast to this it will probably be a relatively long time before this new plant offers competition to large central station units, where cycle efficiencies of 34 per cent have been achieved.

Steam and diesel locomotives are similarly vulnerable to competition from the simple gas turbine. The low cycle efficiency of the steam locomotive of about 10 per cent presents a promising opportunity to the gas turbine plant of substantially twice the efficiency. The high efficiency diesel locomotive is both large and heavy and it presents an opportunity to the very much smaller and lighter gas turbine, which while having lower cycle efficiency burns the very cheapest grade of fuel. These are a few examples of the possible competition this new form may offer existing forms of power generation.

The competition between the continuous power turbines and the intermittent power reciprocating engines is of long duration and each type has established itself in certain fields in some proportion to its inherent merits. The development of the continuous power gas turbine brings certain new and interesting additional advantages to the turbine's position in this competition and the resultng struggle for position will be watched with interest.

It is probably conservative to say that more than $100,000,000 has been expended for research and experiment in the development of the steam turbine.

A Complete Power Plant

The gas turbine is a complete power plant not just a turbine alone. The magnitude of the development job to perfect it is not limited to the development of a single machine, such as a turbine, but must include the development of a compressor of a type heretofore new to this country, as well as the development of a combustion process under conditions that make it new to everyone. One would be optimistic indeed to feel that this entirely new type of power generating plant could spring into perfected existence overnight or even over the span of a few years. Viewed realistically, the promise that the gas turbine holds is now very real and attractive; but it must first be won by the hardest kind of work and development in the research of its component parts. Its ultimate accomplishments will be largely measured by the successful prosecution of the research programs now being initiated. This contribution to industrial development will be made by those having the imagination, technical ability, engineering research and design organizations and the research and manufacturing facilities to get this job done.

EDITOR'S NOTE: An article on the combustion gas turbine, written by F. K. Fischer and C. A. Meyer of Westinghouse Electric and Manufacturing Company will be published in the May issue of *The Petroleum Engineer*.

—— ☆ ☆ ☆ ——

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DEOXIDIZED BESSEMER STEEL

Note These Important Characteristics:

In the following features, comparisons have of necessity been made with basic open-hearth steel of the *same tensile* strength. This has not been done to minimize the well-known features of that steel, but to indicate how in the case of certain applications, DEOXIDIZED Bessemer Steel offers definite advantages.

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★ **Better welding qualities** because of low carbon content.

★ **Lasts longer** under dynamic conditions of loading. Has a higher "endurance limit."

★ **Ductility and toughness are fully equal** to those of steel of same tensile strength.

★ **Ideally suited for bending.** Has higher resistance to failure by buckling. Permits higher design loads.

★ **Fine grain structure.** Minimum of inclusions. Is cleaner.

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DEOXIDIZED Bessemer *Seamless* Pipe offers striking proof of this. It would be difficult to find a severer quality test than the piercing process which produces WALLS WITHOUT WELDS.

That's why you should become familiar with the particular characteristics of this steel. They suggest definite advantages for all 'round improved line pipe service.

DEOXIDIZED Bessemer Steel is not meant to wholly supplant other steels for tubular products; there are some cases where other steels may serve equally well, or better. It is merely another in the great steel family which will be preferred for many pipe applications simply because for such applications it has particular merit.

DEOXIDIZED may be a new word to you when used in this connection. But there is nothing new about it to the metallurgical engineers who developed the process and have watched the performance of hundreds of thousands of tons under exacting conditions of use, time and form.

Watch this steel. You are going to hear much more about it as the time approaches when it can be put into greater production. We predict you will find DEOXIDIZED Bessemer Steel *Seamless* Pipe superior to any you have used before. Descriptive literature sent upon request.

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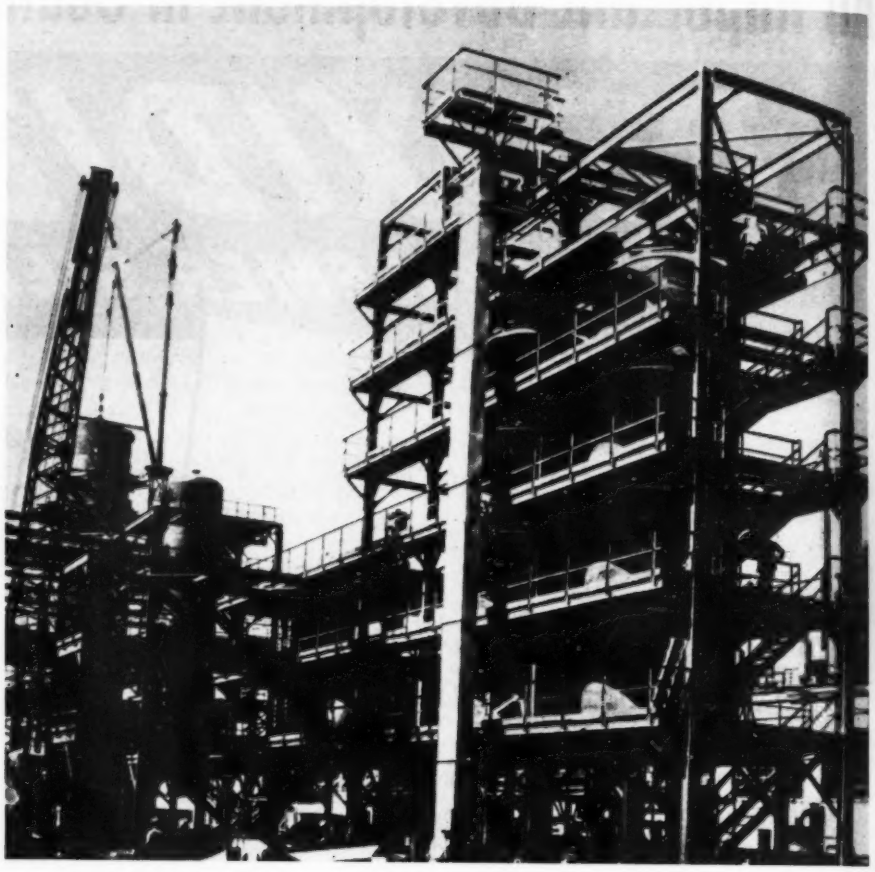
United States Steel Export Company, New York

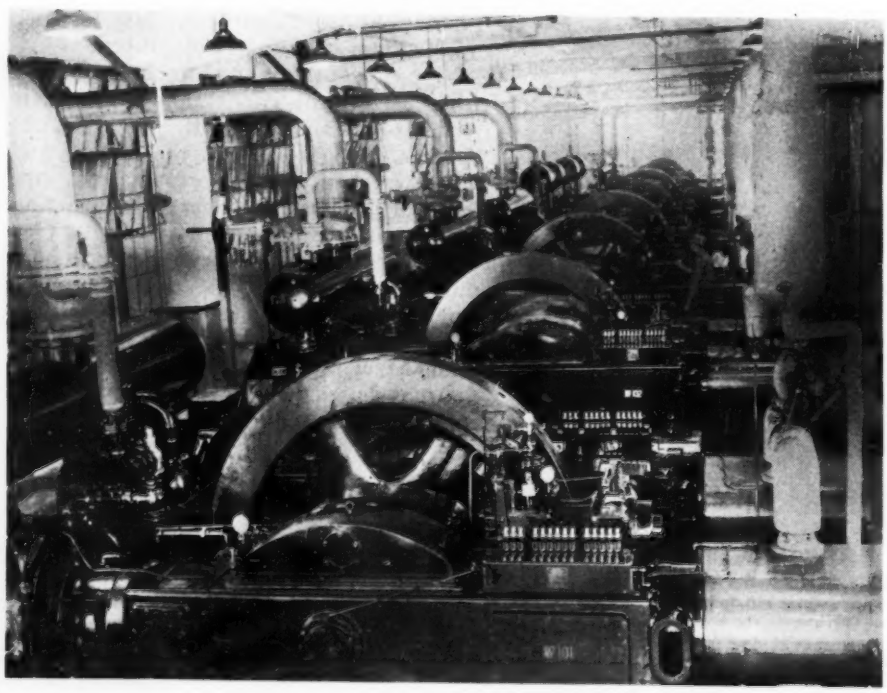
UNITED STATES STEEL



Part of a butadiene plant while under construction

Use of Compressors in Synthetic Rubber Manufacture

☆ Equipment proves essential in many plant processes

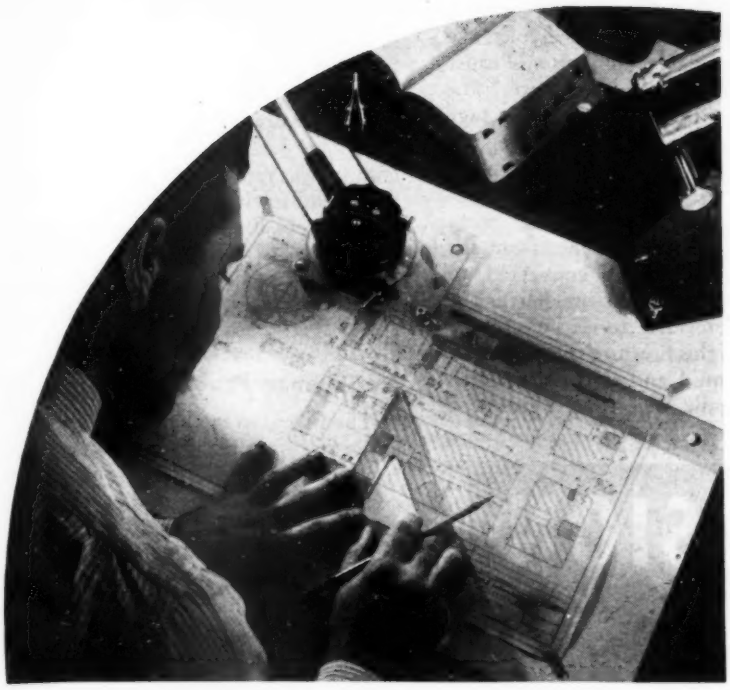


A synthetic rubber plant compressor installation

WHEN we think of synthetic rubber we may easily fall into the habit of considering it only in its solid state; that is, as we see it in many finished products. Before this solid state is reached, however, there are other and more delicate steps to consider.

Before the chief foundation factors of synthetic rubber are brought together, the manufacturer of raw synthetic rubber is dealing with liquids and gases. Butadiene, the principle ingredient in most of our present synthetic rubber production, is a colorless, inflammable gas. It is manufactured from raw products recovered from petroleum, grain, coal, and other sources and becomes a liquid when cooled below the freezing points of water, or it can be liquefied at 70°F. when subjected to a

Article by courtesy of Compressed Air Institute.



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E.L.I. Originally developed the Gamma-Ray or Radioactivity Well Logging (Thru-Casing) Method and currently manufactures the equipment licensed by Well Surveys, Inc., and offered as a service by Lane-Wells Company in the United States and by Seismograph Service Corporation in South America.

E.L.I. Designed for Barnsdall Research Corporation the Hayward Mud Logging Equipment and has manufactured all the units presently used by Baroid in their Mud Logging Service in the United States and Seismograph Service Corporation in South America.

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NEW and IMPROVED Equipment and Services for the Production and Conservation of Petroleum

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EQUIPMENT IN **WORLD-WIDE USE**

pressure of about 22 lb. per sq. in. It is usually handled and transported as a liquid under pressure. Compressors are used in large numbers for this purpose.

As butadiene is manufactured from raw products recovered from petroleum, alcohol, etc., it follows that there are many so called "reactions" that take place during the process. Such reactions result from both chemical and physical influences. Pressure created by compressors is one of these important influences.

In the alcohol series plants now in the production of synthetic rubber there are four main groups of compressors. The first are the hydrocarbon vapor gas compressors. There are more of this first classification than any other, as the gases represent large volumes and must be kept under pressure control. The second group of compressors are 2-stage air compressors of large volume capacities that supply air for reactivating the liquid catalysts. The third group are 2-stage, 70-lb. pressure butadiene compressors. After the gas comes from the catalyst where it was converted to butadiene, these compressors deliver the gas under pressure to large storage tanks. Under this pressure the butadiene becomes a liquid and is thus easier to store and handle. The fourth group of compressors supply compressed air for operating various control instruments, pilot valves, unloading mechanism, and for general plant operation.

In manufacturing butadiene from petroleum rather than from alcohol the compressor applications are of a similar nature, but with the addition of more compressors for refrigeration purposes.

The next step in the manufacture of synthetic rubber, that is, the copolymerization of butadiene and styrene, additional compressors are used.

Copolymer Process

The first step in the copolymer process is the individual making-up of all reactants, with the exception of the copolymers butadiene and styrene. The copolymerization of butadiene and styrene is accomplished in an aqueous solution of these reactants, which include miscellaneous chemicals, anti-oxidents, and catalysts, together with a soap solution as the emulsifying agent. The soap solution is also the "carrier" or medium in which reaction takes place. All these reactants and the emulsifying agent are agitated by air from the compressors mentioned in the first group.

Upon completion of the agitation the charge, which is then a coagulate, is pumped to a blow-down tank where waste gases are vented out.

Up to this point the charge or "batch" consists of a coagulate, ready for washing. After the soap and other unmixed materials are washed out the result is a synthetic latex.

Subsequent steps include the pressing or baling of the rubber for shipment. Compressors are needed to operate pneumatic balers in this step of manufacturing.

Essentially a synthetic rubber plant consists of three major components: (1) A larger number of compressors for making different processing operations; (2) large towers and tanks where conversion takes place as a result of heat, pressure, and catalytic action, and (3) many heat exchangers and a large quantity of piping.

Compressors are also used in plants that process the crude synthetic rubber into finished products. Here the uses of compressed air are in the control and operation of equipment rather than the control of chemical action and reaction as in the case of manufacturing the basic gases and liquids. Huge molds are opened and closed by air pressure. The forming of tires utilizes air pressure, and, as is well known, air pressure follows the tire for the rest of its useful life. For all these pressure needs there must be compressors.

In the alcohol series synthetic rubber plants where it is necessary to have steam generating boilers for the very

with Reilly PIPE ENAMEL

● Protecting crude oil and gasoline pipe lines against corrosion is vital. Corrosion is a costly—and a most persistent—enemy, ever ready to attack steel pipe. For many years REILLY Pipe Enamel has been giving pipe lines thorough and dependable protection against corrosion resulting from moisture, electrolysis, soil acids or alkalies, or other causes; also against soil stress and abrasion.

REILLY Cold Application Coatings give the same dependable protection to storage tanks, structural steel and other exposed metal. Send for booklet on REILLY PROTECTIVE COATINGS.

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17 PLANTS to Serve the Nation

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SEVENTEEN · PLANTS · TO SERVE · YOU

IT'S HERE!

CAMERON
TYPE "Q-R-C"

Quick Ram Change

PRESSURE-OPERATED BLOWOUT PREVENTER

Cameron has begun production of its greatest achievement in drilling control equipment . . . the Type "QRC" Blowout Preventer.

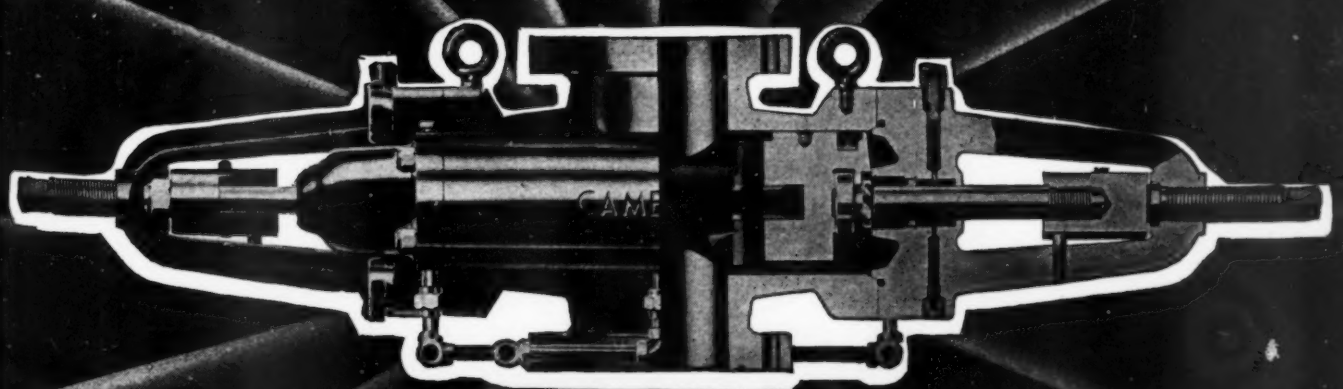
The revolutionary mechanical design of this new control unit includes:

QUICK RAM CHANGE—enabling drilling crews to change largest size rams in *only a few minutes.*
HIGHER RATIO OF CLOSING PRESSURE TO WELL PRESSURE—nearly three times greater than with earlier models.
WELL PRESSURE EQUALIZED FRONT AND BACK OF RAMS —pressure by-pass aids in closing rams . . . automatically holds rams in closed position.
LOW OVERALL HEIGHT—conserves cellar space.
REDUCED WEIGHT—facilitates transport and assembly in well control manifold.

"QRC" design also includes Cameron's famous patented self-feeding ram packing, fluid pressure operation, self-centering rams and other time-tested mechanical features which have made Cameron drilling control units the standard of comparison the world over.

Of necessity, "QRC" production will be limited for the next few months due to allocation of materials and war production schedules. But you will soon be able to buy this sensational blowout preventer which will pay for itself in ram changing time alone!

Completely descriptive literature, now being prepared, will gladly be sent to interested operators on request.



CAMERON IRON WORKS, INC.

711 MILBY ST., HOUSTON, TEXAS

Export: 74 Trinity Place, New York, N. Y. *California:* The Howard Supply Co., Los Angeles

Rocky Mountain: Mountain Sales and Service, Casper, Wyoming

large quantities of exhaust steam in the heat exchangers, all compressors are steam driven. This power availability in the synthetic rubber plant is not only an economy measure and a factor of efficiency, but it also is significant to all industry, inasmuch as it points out the broad potentials of economical compressor uses. In most every industrial plant there is steam in large quantities. The use of this steam to its full efficiency could be realized in many instances by low cost compressor operation to augment other power in the operation of production tools and other equipment.

In the synthetic rubber plants that produce from petroleum gases there is also a readily available source of power for operating the compressors. Here petroleum gas is present in large quantities and therefore all compressors, whether gas compressors or air compressors, are of the gas engine type, using the petroleum gas for fuel.

Many applications utilize compressors in rubber plants as in all manufacturing enterprise. In the manufacture of synthetic rubber, however, compressors are an absolute essential, as the raw materials could not be successfully made and handled without them. In this respect, compressors become one of the prime factors, as well as a credited influence, in the rapid development of an industry that will for all time provide us with the knowledge and the facilities for making all the rubber we want and need.

——— ☆ ☆ ☆ ———

P 094.83

Calculator Determines Line Current

PETROLEUM ENGINEER Exclusive Feature

by V. W. Palen

Westinghouse Electric & Manufacturing Co.

PLANT engineers and electricians will find the accompanying line current calculator useful for quickly determining amperes that will flow in motor and transformer circuits.

The single phase unit solves the equations:

$$I = \frac{H_p \times 746}{E \times PF \times Eff.}$$

(for motor current)

$$I = \frac{Kva. \times 1000}{E}$$

(for transformer current)

Where E = voltage between line wires,

PF = power factor, and

Eff. = efficiency — 87.5 per cent assumed

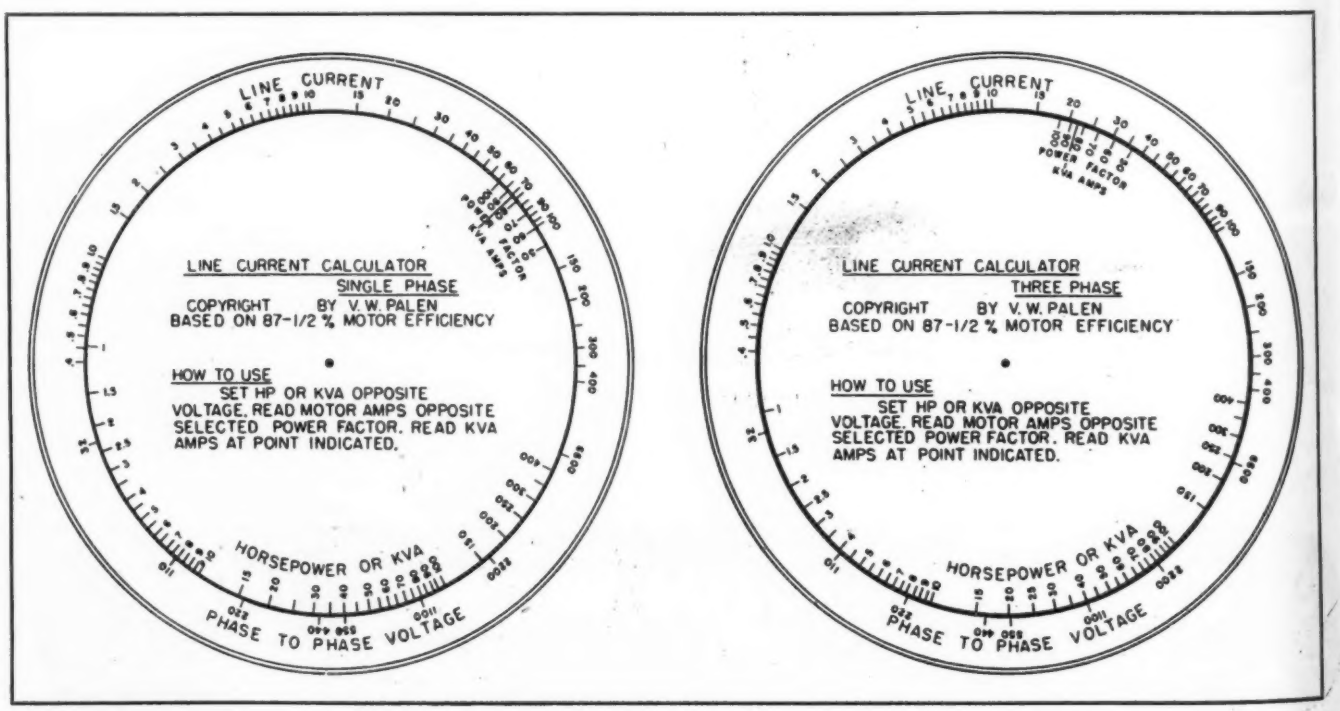
Three phase equations solved by the three phase unit are the same as above except that the denominator of the fraction includes $\sqrt{3}$.

Suppose a 5-hp. single-phase 220-v. motor is to be installed. Set the dial accordingly. Assuming 80 per cent power factor, opposite 80 read approximately 24 amp. Now suppose a 15-kva. three-phase 440-v. transformer is to be installed. Set the dial properly—opposite kva. amp. read approximately 20 amp. With the line current thus determined, proper wire size can be selected to carry the load.

Several voltages that are seldom used around plants are included for the convenience of those who might have occasion to utilize them.

To assemble the calculators cut along the inner and outer circles to make two rings and two disks. Mount these pieces on separate pieces of cardboard using rubber cement. Punch the center holes carefully. Insert brass bolts (with washers) to hold the parts together. Add nuts to the bolts and tighten. The disks should turn easily yet hold their setting. A drop of solder on the nuts makes the assemblies permanent.

——— ☆ ☆ ☆ ———


LINE CURRENT
LINE CURRENT CALCULATOR
SINGLE PHASE
COPYRIGHT BY V. W. PALEN
BASED ON 87-1/2 % MOTOR EFFICIENCY
HOW TO USE
SET HP OR KVA OPPOSITE VOLTAGE. READ MOTOR AMPS OPPOSITE SELECTED POWER FACTOR. READ KVA AMPS AT POINT INDICATED.
HORSEPOWER OR KVA
PHASE TO PHASE VOLTAGE
POWER FACTOR
KVA AMPS
LINE CURRENT CALCULATOR
THREE PHASE
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HORSEPOWER OR KVA
PHASE TO PHASE VOLTAGE
POWER FACTOR
KVA AMPS

Is the Patterson-Ballagh Pipe Wiper good?

These Men Say Yes

DRILLER
"Men work better, less fishing jobs, less blowouts. Make better showing on job."

ROUGHNECK
"Hands and feet dry. Work on dry floors. Clean pipe. Slips grip pipe in freezing weather."

DERRICK MAN
"Drill pipe is dry. Elevators easy to latch. Mud doesn't bother me. Job safer."

TOOL PUSHER
"Less mud weight material to handle. Men quit less. Less stuck drill pipe. Less worry about water supply."

PETROLEUM ENGINEER
"Well completed better as less small junk in hole. Stratas better tested on wildcats. Better chance for completion on schedule, within budget."

SAFETY ENGINEER
"Less danger from slippery floors, infected hands and fire."

DRILLING SUPT.
"Better working conditions. Less well trouble, means better showing for me."

GEOLOGIST
"With no wash water, can tell more accurately absorption of stratas passed through."

PURCHASING AGENT
"Less rush orders for fishing tools, less mud weight material to buy. Cost reduced."

LEASE SUPT.
"Less steel in hole to cause trouble when wells serviced. Heavy oil on work-over jobs eliminated."

Reports from domestic as well as from overseas operations bring astonishing testimonials of the job Patterson-Ballagh Pipe Wipers are doing in service. Now made of PBX artificial rubber, these wipers are oil, gas and weather-resistant. The synthetic rubber, of special formula developed by Patterson-Ballagh engineers, has the essential "snap." It grips the pipe and experience in the field indicates very satisfactory wearing quality.

Users report savings that are unbelievable. They have declared that the saving of one fishing job has paid for the Wipers used for years to come. For example, one user tells us of a fishing job saved that will pay for Pipe Wipers for his wells for the rest of his life.

If you are not now using these Wipers, it certainly will be to your advantage to investigate. Made in all sizes, no tools needed to install.

See Composite Catalog

PATTERSON-BALLAGH
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PATTERSON-BALLAGH

PIPE WIPERS

Baash-Ross News

BAASH-ROSS TOOL COMPANY · LOS ANGELES · HOUSTON · NEW YORK

PETROLEUM ENGINEER EDITION

Are you doing everything possible to save manpower . . . time . . . equipment . . . accidents?

THREE BLOCKS IN ONE
Saves Time! Cuts Inventories!

There's no need to waste crew time while the pusher runs down the right kind of block for the job at hand. Nor need you carry a costly inventory of various types of blocks. Not when you have a BAASH-ROSS UNIVERSAL UTILITY BLOCK!

By means of a simple floor plate attachment, this block becomes a husky Floor Block for all types of snubbing, pulling and snatch-block work.

Attach the beam clamp and you have a Bailing and Coring Block for various hoisting and wire line operations around the rig.

Or, with the clevis attachment, it becomes a Tubing Block for lifting and well-servicing work.

The Block has a side-opening feature to permit quick line threading, has a capacity of 78,000 pounds and is one of the handiest tools you can buy for your rig!

A CLEAN RIG MEANS SAFER, FASTER WORK!

Isn't it shortsighted to put valuable, hard-to-get crews out on bailing and other wire line jobs and have them waste time and risk dangerous accidents slipping around on mud or oil smeared floors?

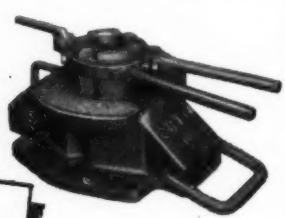
Particularly when it's so easy to equip your rigs with a BAASH-ROSS WIRE LINE WIPER that is *completely automatic* in operation. When the tools are lowered into the hole the Wiper automatically drops into place, locking itself so that line friction cannot loosen it as the tools are brought out again. Then, as the tools are withdrawn from the well, packing in the Wiper cleans all mud and oil from the line, confining the gas and fluid to the flow lines and keeping the rig floor *dry* and *clean*. The instant the rope socket strikes the packer assembly the lock releases and the Wiper rides out of the hole on top of the tools. It's simple, and requires no attention whatever from the crew—no flagging, no line marking, nothing to slow down or hamper rig operations!

Running position.

Sizes to fit all jobs from 3" line pipe to 9" casing!

Released position.

QUICK TO INSTALL AND REMOVE
THIS SPIDER HOLDS HEAVIEST LOADS



Here's a Tubing Spider that will enable your crews to set up quicker, work faster and safer, and move on to the next job sooner!

First, note how easily this BAASH-ROSS OPEN END TUBING SPIDER is to install. Simply remove the dovetailed solid steel end gate, slip the spider around the tubing and drop the gate back in place again. No need to break tubing connections or head fittings!

Then note how unusually rugged the end gate connection is. Dovetailed tongues on each side of the gate mate with corresponding grooves in the spider to form a solid assembly that will not spread under the heaviest loads. For added safety the gate is held in place by a heavy bolt that passes through both sides of the body.

And when running tubing, the unitized slip assembly gives extra speed and efficiency. The four slip segments are locked in *permanent* alignment—act as a single unit in gripping the pipe. This eliminates uneven slip pressure, protects the tubing against damage and prevents slipping. Your crews work faster, more safely and finish quicker!

Remove end gate and slip spider into place. No need to break connections.

Note tongues in gate that mate with the spider to form rigid assembly.

Unitized slip assembly acts as unit, grips uniformly, protects pipe.

STREAMLINED SAFETY
A Tubing Block That Speeds Rig Work!

During most production operations the rig is crowded with tubing, rods and other equipment that cramps working space. Conventional tubing blocks have sharp angles, projecting bolts, etc., that catch in this equipment, slowing down operations and endangering the crew.

But not the BAASH-ROSS STREAMLINED TUBING BLOCK! Here's a block that's *completely* streamlined from top to bottom. All corners are rounded, and even bolts, grease nipples and other small parts are recessed flush!

And that's only *one* feature. In addition, each bearing has positive, easy-to-reach, individual lubrication ducts. Bearings are oversize for heavy duty work. And the case is so designed that by removing one guard, the block can be easily rolled about on the sheaves to facilitate handling and transporting!

Protect your workmen, speed up your rig operations, reduce risks in close-quartered production jobs by using this Baash-Ross Block. Available in 1, 2 and 3 sheave sizes, each with 20", 24" or 30" sheaves. Capacities 60,000 to 200,000 lbs.

THE *Petroleum* Engineer's CONTINUOUS TABLES

A DAILY REFERENCE FOR OPERATING MEN

INSTALLMENT NO. 82

A VALUABLE and regular feature of *The Petroleum Engineer,* the Continuous Tables, now in their seventh year of publication, were designed to save time and effort for the technician and the practical field or plant worker. The tables have proved one of the most popular and helpful departments of *The Petroleum Engineer.* Data are presented in the simplest form available with many types of information included that are best presented by curves or nomographs when three or more variables must be considered simultaneously.

The Continuous Tables have developed as a result of suggestions for new tables, direct contributions, and improvements to existing tables by members of the petroleum and related industries, including manufacturing concerns, who are continually searching for practical information reduced by computation to tabular form readily applicable to the problems daily confronting them that might otherwise necessitate a more or less tedious calculation. These contributions and suggestions from the industry have resulted in a valuable exchange of information and data contributing to the progress of the industry as a whole.

This index will be revised monthly. The index for installments 1-12, inclusive, will be found in the May, 1938, issue; 13-24, inclusive, in the June, 1939, issue; 25-36, inclusive, in the June, 1940, issue; 37-48, inclusive, in the June, 1941, issue; 48-60, inclusive, in the June, 1942, issue; 61-72, inclusive, in the June, 1943, issue, and 73-79, inclusive, in the January, 1944, issue.

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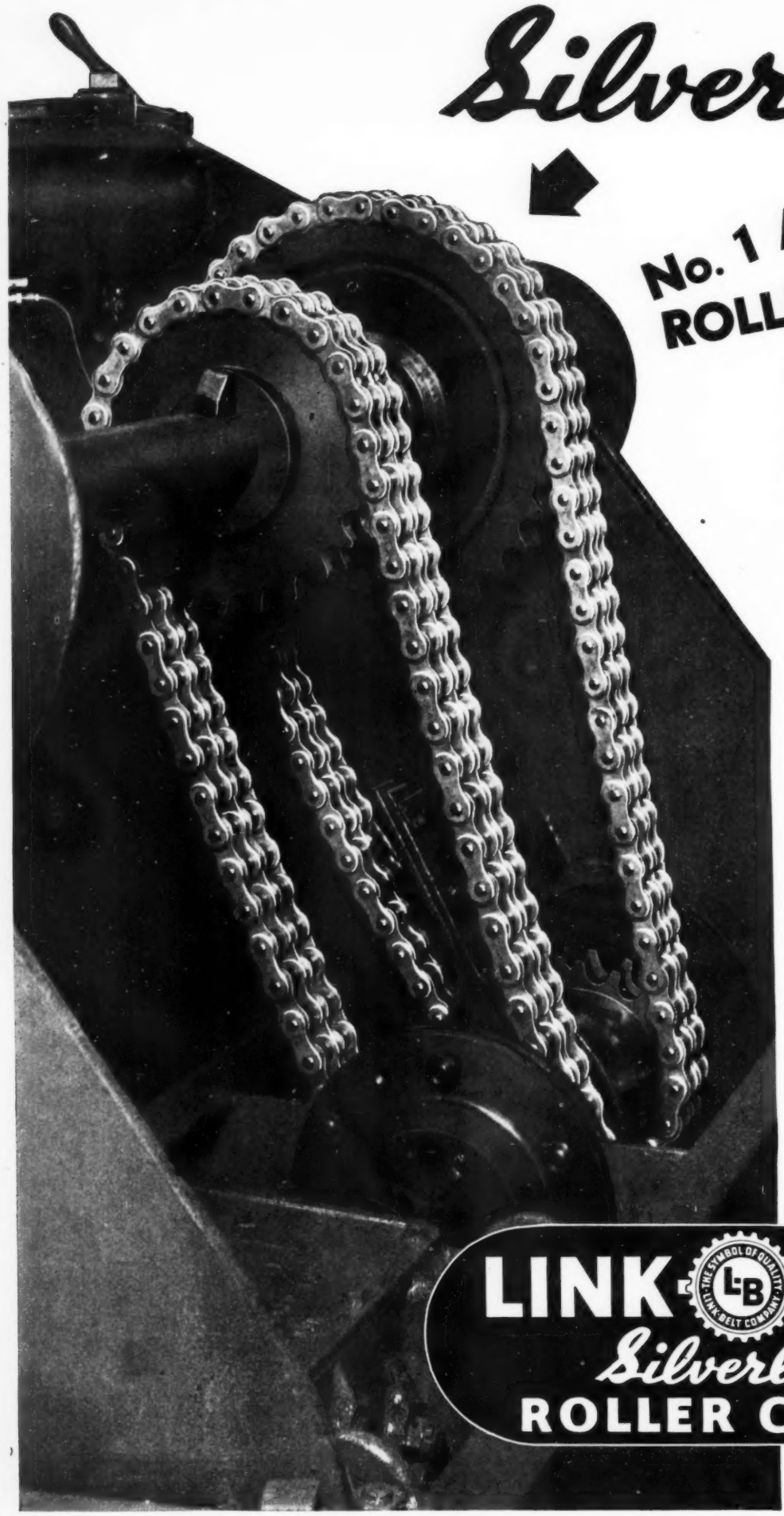


Silverlink...

No. 1 AMONG ROLLER CHAINS

● This modern, high speed, portable drawworks is chained up to drill to pay sand with maximum speed and efficiency, and with minimum trouble. Among its numerous advantages is the combination of Link-Belt *Silverlink finished steel roller chain and sprockets, a section of which is pictured here.

Rig manufacturers, like rig owners, agree on Silverlink . . . that its accurately finished all-steel construction, high standards of precision, great strength yet light weight, flexibility, and its ability to withstand shock make it the top performer in roller chains. They can safely depend on Silverlink. Link-Belt's 68 years of continuously improving chain is their insurance.

LINK-BELT COMPANY

Builders of the Most Complete Line of Power Transmission Machinery

Indianapolis 6, Dallas 1, Houston 2, Los Angeles 33, Kansas City 6, Mo., New York 7, Toronto 8. Distributors in all fields.

*In cooperation with the government conservation program, Silverlink roller chain will hereafter be furnished in a durable "blackout" finish. 9481

LINK-BELT
Silverlink
ROLLER CHAINS

ROTARY DRILLING LINE TON-MILE CHART

The alignment chart shown below was constructed from Formula (1). On this chart correction for the additional weight due to tool joint, less the loss of weight due to buoyancy of mud weighing 75 lb. per cu. ft. is indicated. Although the weight of mud is sometimes much greater, 75 lb. per cu. ft is used as a representative figure. The chart permits the use of other figures if necessary.

In the chart the value used for "E" was 100 feet, which was taken as a convenient compromise between 90 ft. and 120 ft. stands.

Formula: $T.M. = D_2\,(E+D_2)\,(0.0000000946\,Wm)+D_2\,(0.000000379)\,(M+0.5C)$ .....(1)

B = weight of rotary mud in lb. per cu. ft..
C = excess drill collar weight with allowance for buoyancy equal to: (L x Cm)—(L x V
Ca = weight per ft. of drill collar in air, in lb.
Cm = weight per ft. of drill collar in mud, equal to: Ca (1—0.002B) lb.,
D_1 = initial depth of hole, in ft.,
D_2—Final depth of hole, in ft.,
E = length of drill pipe stand, in ft.,
L = length of drill collar assembly, in ft.,
M = total weight of block, hook, links, and elevator, in lb.,
N = number of stands of drill pipe,
R.T. = round trips,
T.M. = ton miles,
Wa = weight per ft. of drill pipe in air, lb., and
Wm = weight per ft. of drill pipe in mud, equal to: Wa (1—0.002B) lb.

This formula embodies the following assumptions and cycle of operations in drilling:

Assumptions

1. When the pipe is in the hole, it is under the full buoyant effect of the mud.
2. The unit weight of the pipe includes the weight of the tool joints.
3. The bit assembly has the same unit weight as the drill collars.
4. Friction going in the hole balances and offsets that coming out.
5. The drill collar and bit assembly have their weights concentrated in the first stand.
6. The unit weight of drill pipe is the nominal weight specified by A.P.I. Stds. 5-A. The lengths are 21 ft., 29 ft., and 42 ft. for ranges 1, 2 and 3. respectively.

Cycle of Operation in Drilling

1. Drill ahead length of the kelly.
2. Pull up length of the kelly.
3. Ream ahead length of the kelly.
4. Pull up length of the kelly to add single or double.
5. Put kelly in rat hole.
6. Pick up single or double.
7. Lower drill stem in hole.
8. Pick up kelly.

Drilling Ton-Mile Formula

The relationship between the round trip and drilling ton mile, is expressed as follows:

T.M. Drilling $[(TM_{RT})\,D_2-(TM_{RT})\,D_1]$ ....(2)

In which $(TM_{RT})\,D_1$ represents the ton miles for a round trip at the depth D_1 where drilling is started after going in, and $(TM_{RT})\,D_2$ represents the ton miles for a round trip at the depth D_2 where drilling is stopped before coming out of the hole. This simple relationship may be inferred by studying the "Cycle of Operations in Drilling". For any one hole, the sum of all operations 1 and 2 is equal to one round trip, the sum of all operations 3 and 4 is equal to another round trip, the sum of all operations 7 is one-half a round trip, and the sum of all operations 5, 6, and 8 may, and in this case does, equal another one-half round trip, thereby making the equivalent three round trips to bottom, the work of drilling the hole. This relationship also allows the ton-miles for drilling to be computed easily by the ton-mile chart.

The formula given herein is recommended by the A.P.I. for use in evaluating service from rotary drilling lines.

Example:

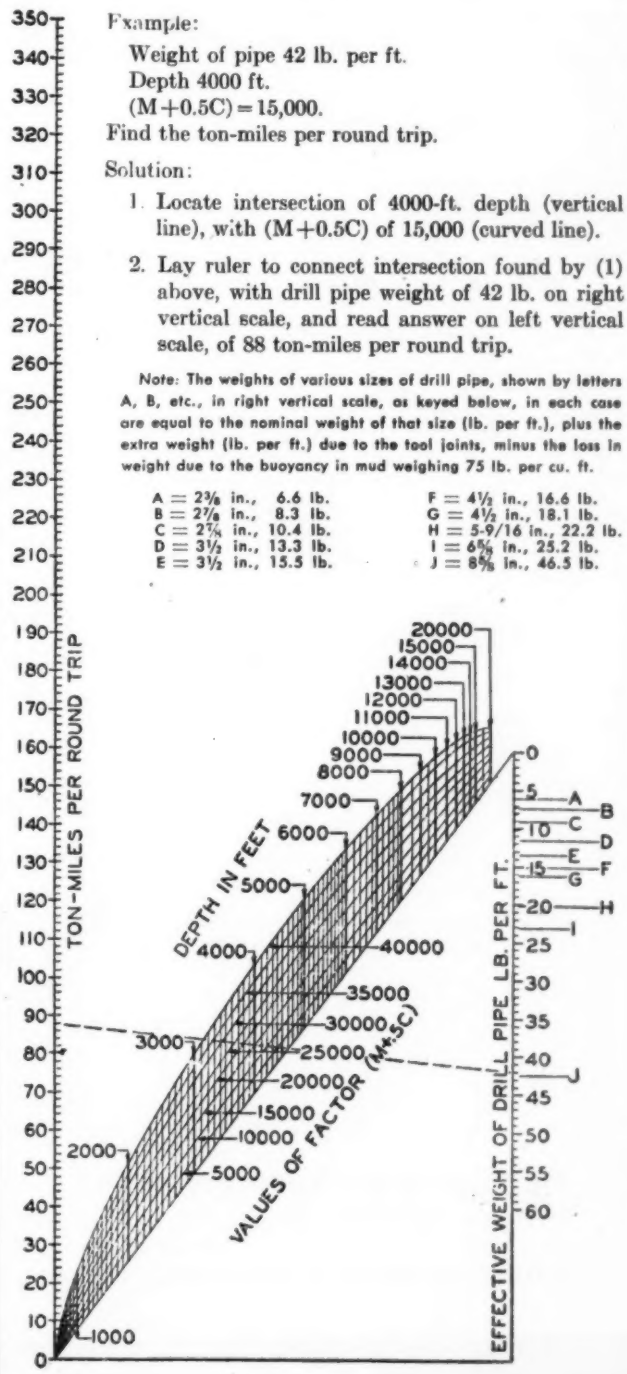
Weight of pipe 42 lb. per ft.
Depth 4000 ft.
(M+0.5C) = 15,000.
Find the ton-miles per round trip.

Solution:

1. Locate intersection of 4000-ft. depth (vertical line), with (M+0.5C) of 15,000 (curved line).
2. Lay ruler to connect intersection found by (1) above, with drill pipe weight of 42 lb. on right vertical scale, and read answer on left vertical scale, of 88 ton-miles per round trip.

Note: The weights of various sizes of drill pipe, shown by letters A, B, etc., in right vertical scale, as keyed below, in each case are equal to the nominal weight of that size (lb. per ft.), plus the extra weight (lb. per ft.) due to the tool joints, minus the loss in weight due to the buoyancy in mud weighing 75 lb. per cu. ft.

A = 2⅜ in., 6.6 lb.
B = 2⅞ in., 8.3 lb.
C = 2¼ in., 10.4 lb.
D = 3½ in., 13.3 lb.
E = 3½ in., 15.5 lb.
F = 4½ in., 16.6 lb.
G = 4½ in., 18.1 lb.
H = 5-9/16 in., 22.2 lb.
I = 6⅝ in., 25.2 lb.
J = 8⅝ in., 46.5 lb.



—Chart from American Petroleum Institute Specification for Wire Rope, Appendix D.

LAY·SET *Preformed* IS FREE

The preforming process frees **LAY-SET** Wire Rope of muscle-bound stresses. Being preformed, Hazard **LAY-SET** is not hampered by needless strains. Rather, every wire and strand is free to do its full share of work from the very first hour it is put on your machine.

Hazard **LAY-SET** Preformed is a "pre-broken-in" rope; it resists snarling and kinking; it handles easier, faster, safer and cheaper. It possesses high resistance to bending fatigue and so lasts longer—much longer than non-preformed wire rope. Regardless of where or how you use wire rope, whether for running or standing service, specify Hazard **LAY-SET** Preformed—the rope that gives you greater dollar value.

Hazard **LAY-SET** Preformed Wire Rope is "in the service" on countless jobs for the Armed Forces where it is proving its many advantages. Specify it for *your* use.

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AMERICAN CHAIN & CABLE COMPANY, INC. • BRIDGEPORT, CONNECTICUT

ARMY E NAVY

GREEN SIGNIFIES SAFETY

HAZARD LAY·SET *Preformed* ROTARY LINES

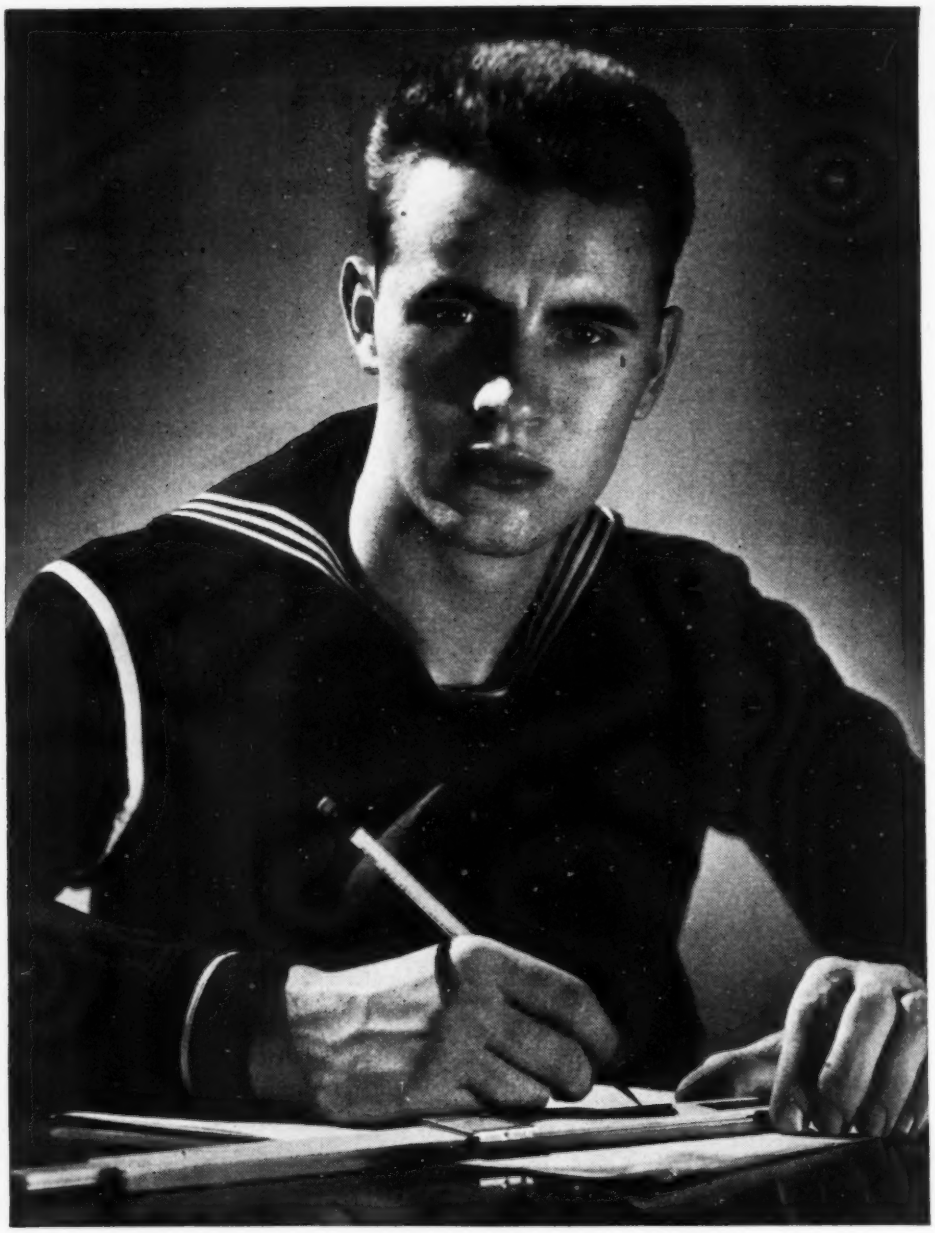
PHYSICAL CONSTANTS OF HYDROCARBONS

Hydrocarbon	Specific gravity 20/4 °C.	M. P. °C.	B. P. °C.	Index of refraction n_D^{20}	Viscosity Abs. Poises	Spec. heat	Heat of vaporization Cal/G.	Heat of combustion K-Cal/mol.	Aniline point °C.	Coeff. of expansion °C.	Critical constants P Atm.	Critical constants T °C.	Critical constants D	Vapor pressure °C.	Vapor pressure mm.	Octane number Actual	Octane number Blending	Surface tension Flash °C.
$C_{11}H_{24}$ Undecane	$\frac{5.396^{air}}{0.74025}$	−25.62	195.8	1.41727	0.011717^{20} 0.0086440	0.524^{25}	58.5	1775.3p	80.6	0.0009678^{0-30}	19.9	369.4	0.228	75.2 126.6	11 100			
$C_{12}H_{26}$ Dodecane	$\frac{5.86^{air}}{0.74876}$	−9.60	216.26	1.42156	0.0135325	0.521^{25}	54.9	1932.4p	83.7	0.0009619^{0-30}	18.5	390.6	0.2255	92.0 169.5 190.0	10.1 224.0 437.0			 73.9
$C_{13}H_{28}$ Tridecane	0.7567	− 6.2	236.5	1.4250^{25}	0.0242^{20} (S) 0.010480	0.4896^{0-50}	51.5	2110.5	87.0 cst	0.0009166^{0-30}	17.5	410.0	0.2240	107.3 162.0	11 100			
$C_{14}H_{30}$ Tetradecane	$\frac{6.8314^{air}}{0.7632}$	5.5	253.5	1.42886	0.0217820 0.0125950	$0.523^{17.5}$	48.2	2271.0	89.5 cst	0.000893	16.56	427.8	0.2220	122.3 178.3	11 100			20.2 100.0
$C_{15}H_{32}$ Pentadecane	0.7689	10.0	272.7	1.431^{25}	0.028122	0.4966^{0-50}	44.9	2415.4p	92.0 cst	0.0008753^{0-30}	15.75	444.4	0.2212	136.6 193.6	11 100			
$C_{16}H_{34}$ Hexadecane	0.77335	18.14	286.5	1.43435	0.035162^{20} 0.018585^{50}	0.495^{0-50}	41.9	2556.1p	95.1	0.0008045^{0-30}	15.10	461.1	0.2205	150.0 208.1	11 100			27.66 110.0
$C_{17}H_{36}$ Heptadecane	0.7783	21.0	305.8	1.4360	0.0415^{30} (S) 0.015690	0.6218	39.3	2743.2	98.0 cst		14.4	476.1	0.2195	162.9 221.8	11 100			24.175
$C_{18}H_{38}$ Octadecane	0.7822	28.0	317.9	1.4344^{32}	0.0452920 0.0234450	0.6357	36.5	2903.2	100 cst		13.8	490.6	0.2186	174.9 234.9	11 100			27.58^{32}
$C_{19}H_{40}$ Nonadecane	0.7857	31.4	336.2	1.4356			34.2	3021.8	102.0 cst		13.43	502.8	0.2203	186.4 248.0	11 100			
$C_{20}H_{42}$ Eicosane	0.7888	36.7	205.0	$1.434^{42.9}$		0.512^{6}		3183.1p	105.0 cst		13.6	500.0		198.0 223.4	11 30			
$C_{21}H_{44}$ Heneicosane	0.7585 70	40.4	172—172.5 $^{2.5}$	1.4240	0.0478^{50} (S) 0.0183110		45.0	3335.1	107.0 cst		12.4	527.7		209.0 235.0	11 30			
$C_{22}H_{46}$ Docosane	0.7782 44	45.7	203.0	1.4400		0.5590^{48-73}		3491.4	109.0 cst		12.1	538.9		220.0 246.0	11 30			
$C_{23}H_{48}$ Tricosane	0.7785 47	47.0	240.0 ^{15}	1.420^{90}				3693.6	112.0 cst		11.7	540.0		230.0 256.4	11 30			
$C_{24}H_{50}$ Tetracosane	0.7682 70	49.4	250.0	1.4288^{70}				3863.3	114.0 cst		12.0	561.5		240 267	11 30			
$C_{25}H_{52}$ Pentacosane	0.7785 60	53.3	259.0	1.4380^{60}		$0.521^{21.5}$		3941.5p	116.0 cst		11.1	572.1		250 277	11 30			

See table P 771.001. B for footnotes.

Table from "Physical Constants of the Principal Hydrocarbons," 4th edition, by M. P. Doss, by courtesy of copyright owner, The Texas Company.

The man behind the Future



Behind our fighting forces is the greatest production effort in the history of the world.

Behind our production effort are the men of science... engineers, designers, researchers, mass-production experts.

Behind these mechanical wizards are the engineering students... the men of tomorrow on whose shoulders rests America's industrial future... your future.

These young men... many already in uniform... are passing up their football and hockey and best girls to cram four-year engineering courses into less than two years.

They are getting behind the war effort. The things they've learned are already at work in America's planes, tanks, guns, and ships.

And behind these students... with endless patience and devotion, giving freely of their minds and hands and time... are the veteran teachers.

Also backing them are America's leading industrial organizations... taking time, though busy on war jobs, to help these youngsters foresee the use and shape of future mechanical equipment.

Hyatt, for instance, regularly provides data of helpful interest for these knowledge-hungry engineers.

Our latest contribution is the Hyatt Engineering Handbook... a quick-reference manual containing a collection of original computations and other fundamental engineering data.

Such is the American way of getting things done, of planning ahead, of imparting knowledge to builders of tomorrow, of cultivating coming men as well as those who have arrived.

We've all got a stake in these young men. The stake is our future... America's future.

Let's give them all we've got.

HYATT BEARINGS
DIVISION OF
GENERAL MOTORS
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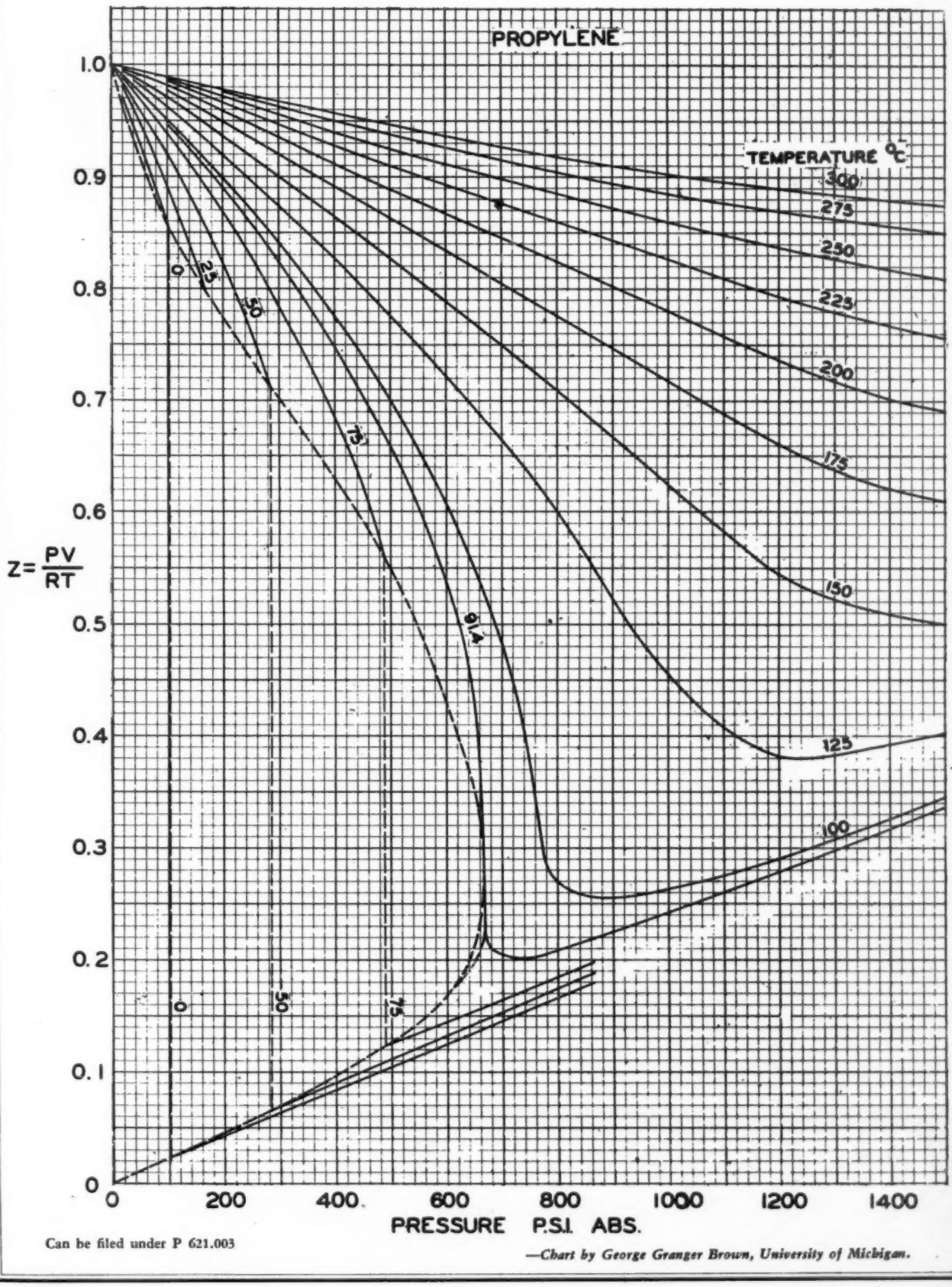
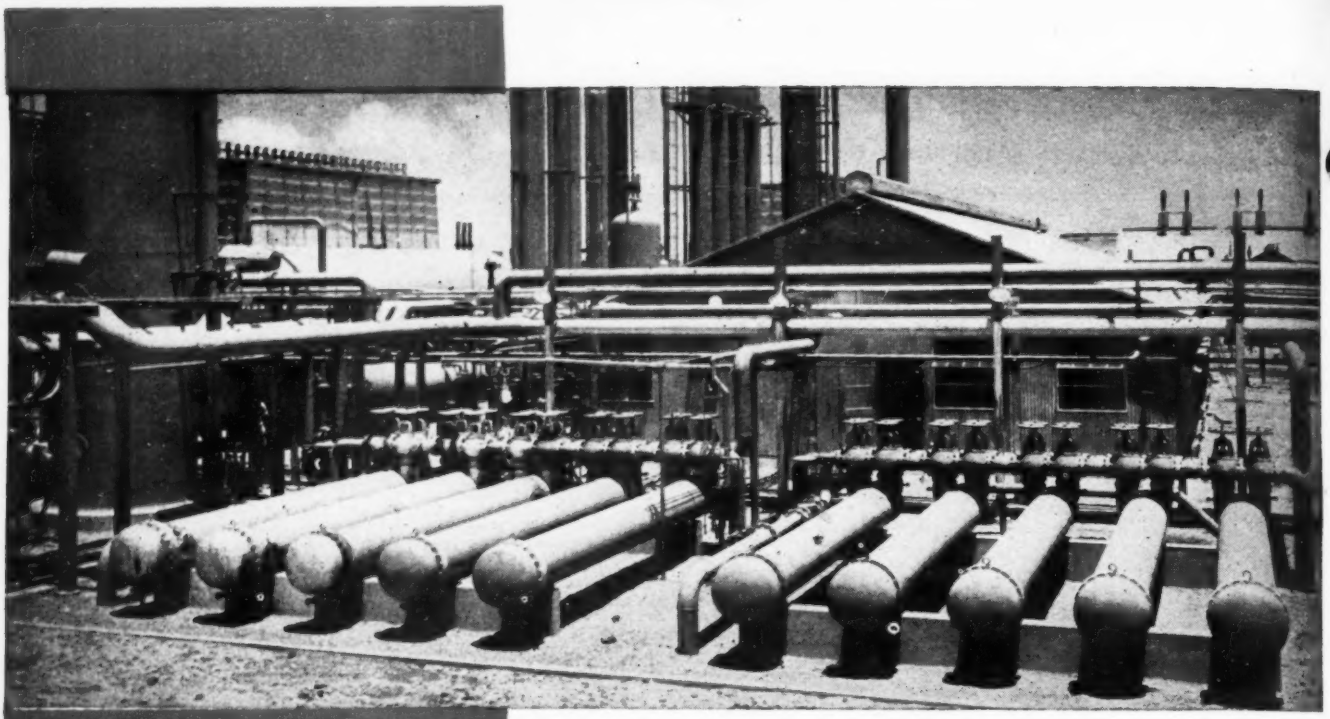
COMPRESSIBILITY FACTORS FOR PROPYLENE AT ABSOLUTE PRESSURES

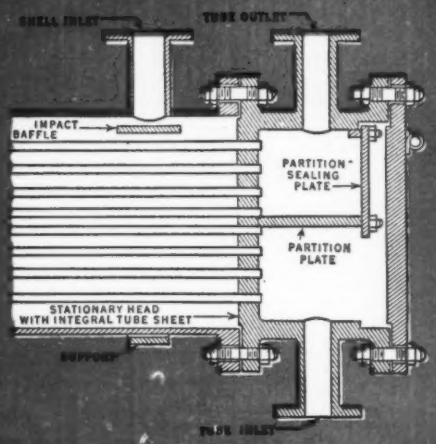


Can be filed under P 621.003

—Chart by George Granger Brown, University of Michigan.



SHELL-and-TUBE EXCHANGERS that FIT the job



PARTITION SEALING PLATE

One of the features of the G-R Shell-and-Tube Exchangers . . . assures leak-proof joints between passes in stationary and floating heads, without requiring the stay-bolts through cover plates that are difficult to keep tight at high temperatures and pressures. Write for Bulletin 915 describing in detail this and other features of G-R Shell-and-Tube Exchangers.

NOTE: The forty three-way valves shown in the installation photograph are also of G-R manufacture.

When you install a G-R shell-and-tube exchanger, you receive many benefits that are not reflected in the price:

MOST SUITABLE DESIGN . . . because the many different types of G-R heat transfer apparatus allow impartial recommendations and a selection of type of unit and design details that best meet individual requirements.

ASSURANCE OF REQUIRED PERFORMANCE . . . because the authoritative G-R designs are based on 77 years of experience in building heat transfer apparatus for every conceivable service.

CORRECT CONSTRUCTION . . . sturdy proportions and accurate machine work that assure proper fitting of all parts and also freedom from undue maintenance expense.

EXCLUSIVE FEATURES . . . based on the continuous pioneering work of the oldest and largest specialists in heat transfer apparatus.

THE GRISCOM-RUSSELL CO.
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Pioneers in Heat Transfer Apparatus

HEAT TRANSMISSION THROUGH FURNACE WALLS

This series of charts is intended to facilitate the solution of two problems commonly encountered in the design of industrial furnaces. The problems are as follows:

1. Determination of cold-face temperature and heat loss when hot-face temperature, thickness of wall and conductivities of the materials are known.
2. Selection of materials and thickness of wall (of one or more components) to give desired cold-face temperature of heat loss when hot-face temperature is known.

Use of the charts permits a rapid comparison of the efficiency of two or more materials or combinations of materials. Knowing the conductivity factors of the various materials under consideration, the designer can select a wall section with optimum heat transfer characteristics to meet the requirements of the installation.

The K-factor, the measure of unit conductivity, is the basic element in heat transfer calculations. Considerable variation exists in the available data on many refractory and insulating materials. This condition is being rapidly improved as the conductivity factors of old and new materials are being determined by standardized procedures.

The curves in the charts are plotted in terms of conductivity factors (K) in order to make them adaptable to any of the materials commonly used in the construction of most industrial furnaces. This arrangement also permits the use of more accurate conductivity data that may later be developed for specific materials.

Formulas and material for calculation of the charts was obtained from "Recommended Procedure for Calculating Heat Losses Through Furnace Walls," Manual of American Society for Testing Materials Standards on Refractory Materials. All temperatures are in degrees Fahrenheit. The outside surface of furnace wall is considered as exposed refractory or steel jacket, with an ambient atmosphere of still air at 80°F.

Directions for Use of Charts

Fig. 1 and Fig. 2 are one component wall charts. Select the chart corresponding to the known K-factor. Find the known hot-face temperature on the left hand vertical scale and move across the chart to the given wall thickness. The cold-face temperature may be read directly from the lower scale and the heat loss in B.t.u. per hr. per sq. ft. on the upper scale.

The dashed line curves on the chart are for standard thickness of brick walls. Solid curves may be used for selection of proper wall thicknesses when materials such as refractory concrete are used and the designer is not limited by standard-size units.

Fig. 1. Wall of one component, K = 2.0

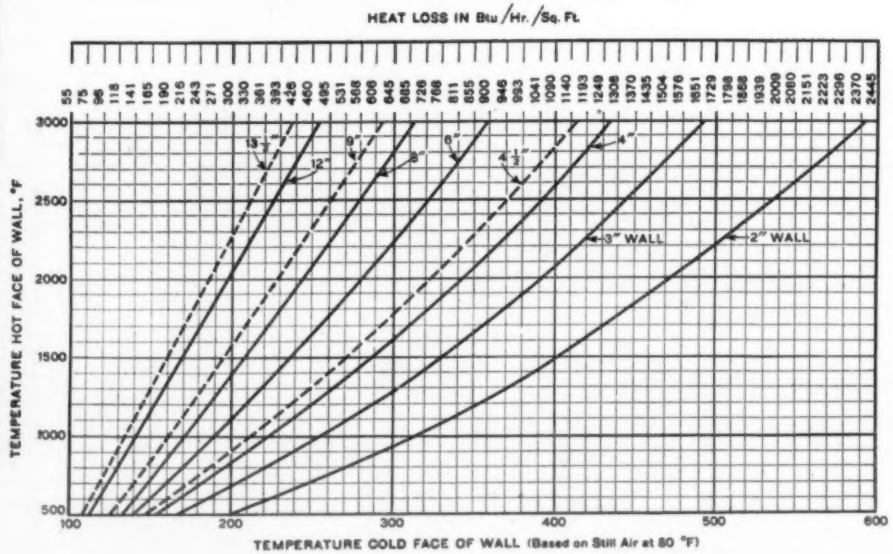
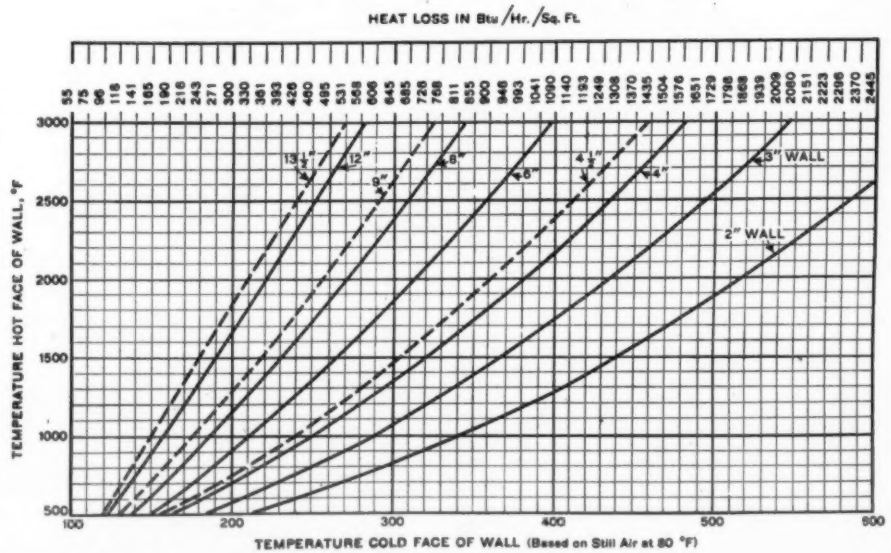
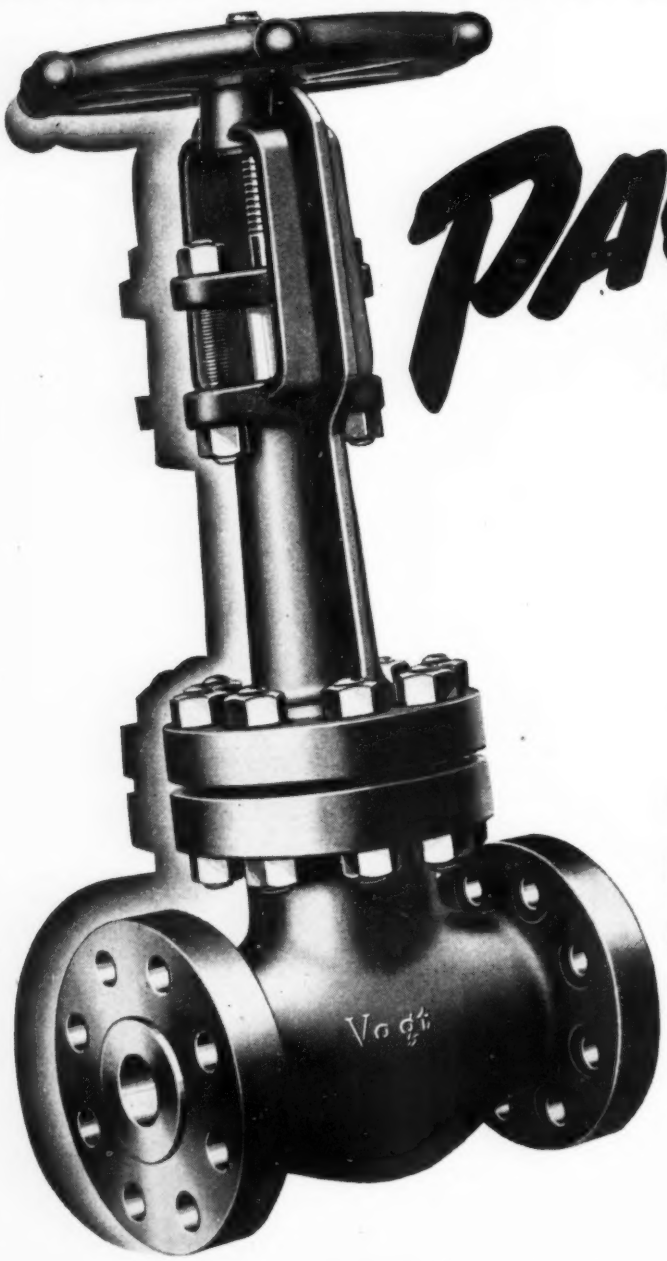


Fig. 2. Wall of one component, K = 2.5



This series of tables by courtesy of copyright owner, The Atlas Lumnite Cement Company.

STILL SETTING THE PACE!



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DROP FORGED STEEL VALVES

continue to give thoroughbred performance in pipe lines where the "heat is on" in high-octane gasoline, synthetic rubber, powder, chemical and hydraulic plants, as well as naval and marine service.

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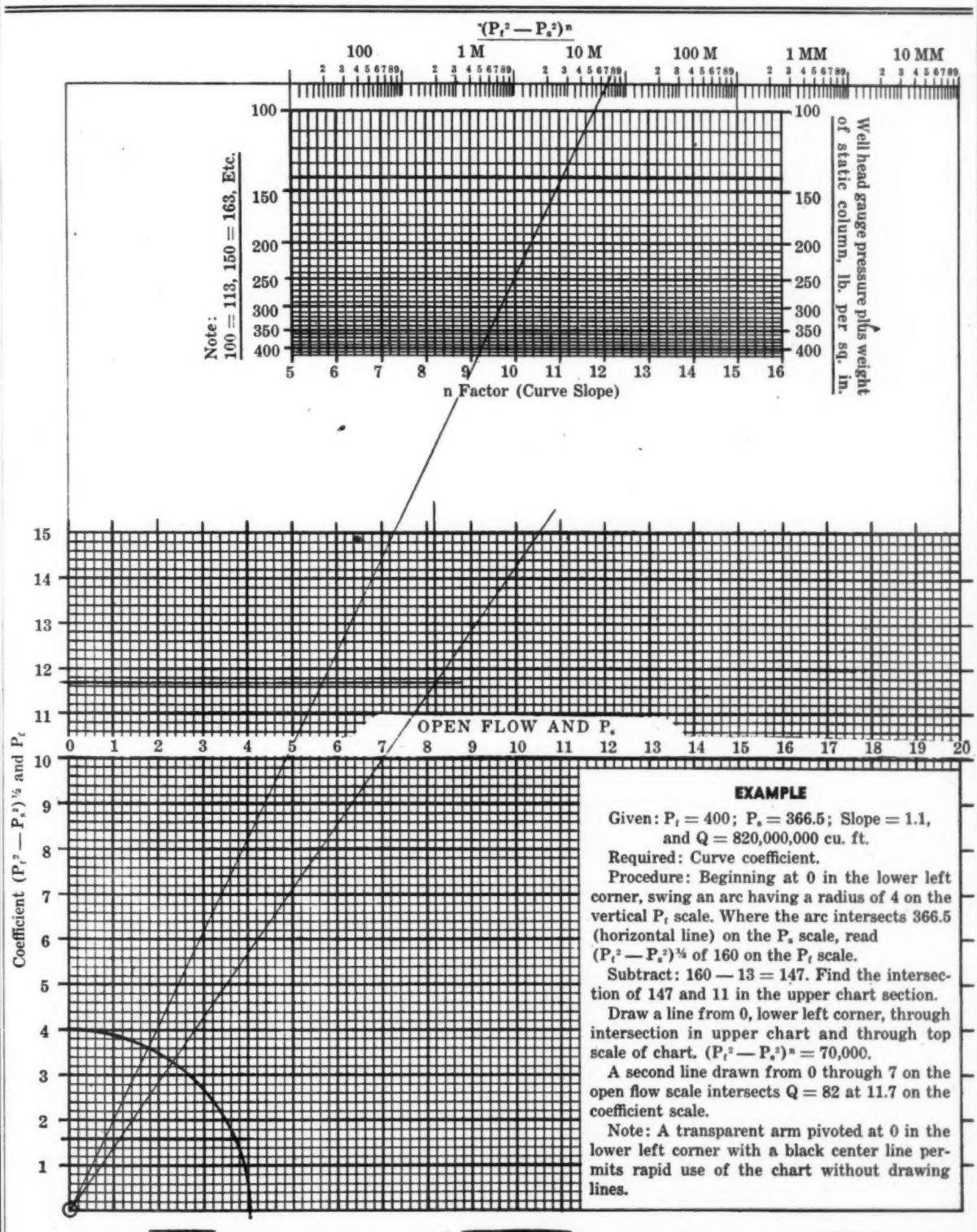
BACK PRESSURE OPEN FLOW COMPUTER


$(P_t^2 - P_s^2)^n$
100
1 M
10 M
100 M
1 MM
10 MM
Note: 100 = 113, 150 = 163, Etc.
n Factor (Curve Slope)
Well head gauge pressure plus weight of static column, lb. per sq. in.
OPEN FLOW AND P_s
Coefficient $(P_t^2 - P_s^2)^{1/2}$ and P_t

EXAMPLE

Given: $P_t = 400$; $P_s = 366.5$; Slope = 1.1, and Q = 820,000,000 cu. ft.

Required: Curve coefficient.

Procedure: Beginning at 0 in the lower left corner, swing an arc having a radius of 4 on the vertical P_t scale. Where the arc intersects 366.5 (horizontal line) on the P_s scale, read $(P_t^2 - P_s^2)^{1/2}$ of 160 on the P_t scale.

Subtract: 160 — 13 = 147. Find the intersection of 147 and 11 in the upper chart section.

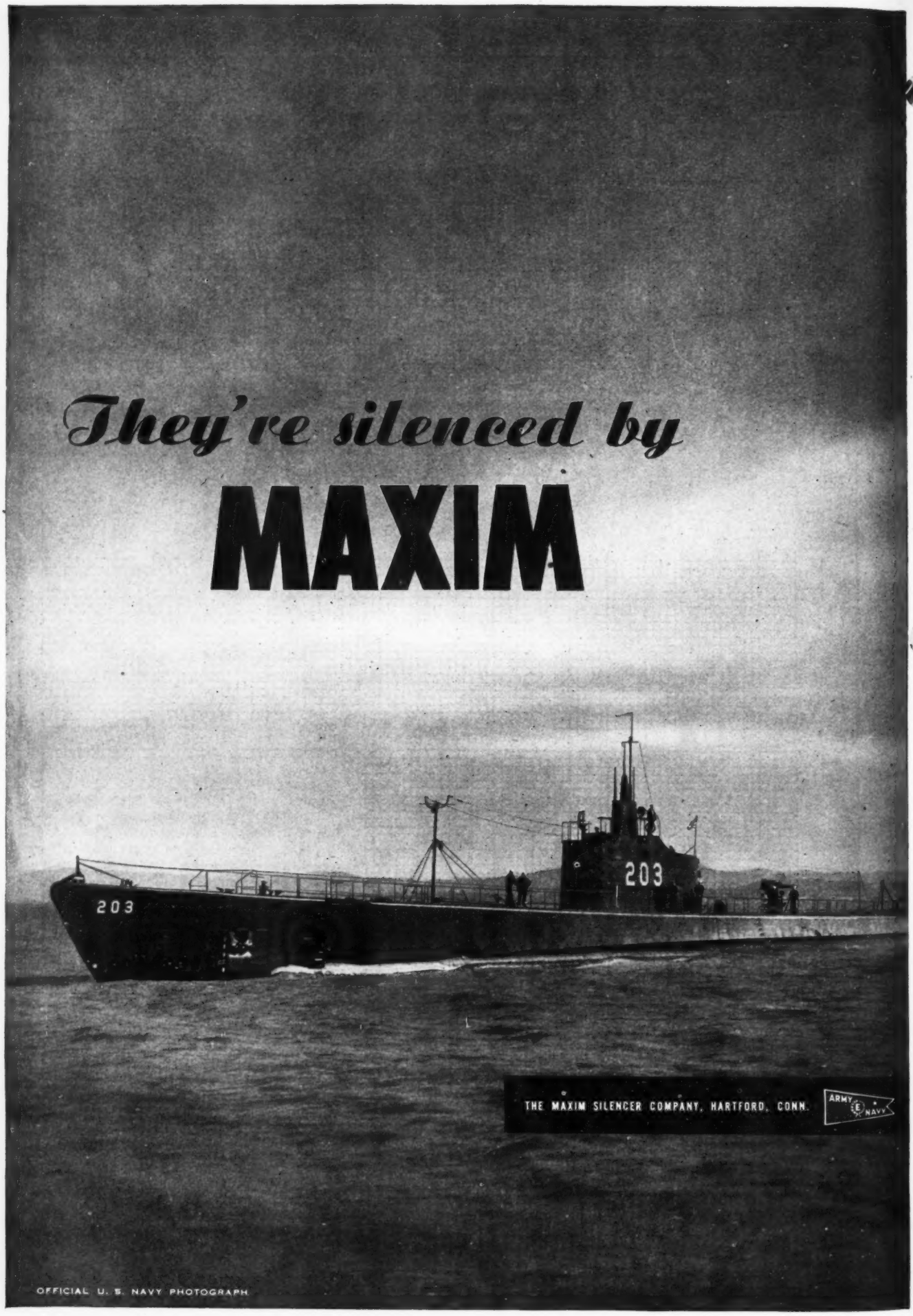
Draw a line from 0, lower left corner, through intersection in upper chart and through top scale of chart. $(P_t^2 - P_s^2)^n = 70{,}000$.

A second line drawn from 0 through 7 on the open flow scale intersects Q = 82 at 11.7 on the coefficient scale.

Note: A transparent arm pivoted at 0 in the lower left corner with a black center line permits rapid use of the chart without drawing lines.

To find open flow for any rock pressure (well head pressure lb. per sq. in. ga. plus weight of static column) draw a line from O lower left corner to the intersection of pressure and n-factor in upper chart. Read $(P_t^2 - P_s^2)^n$ on top scale. Transfer this reading to open flow scale and draw a line from O to the reading. At intersection of coefficient and the line read the open flow.

—Chart by William F. Martin, Texoma Natural Gas Company, Amarillo, Texas.


They're silenced by
MAXIM
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THE MAXIM SILENCER COMPANY, HARTFORD, CONN.
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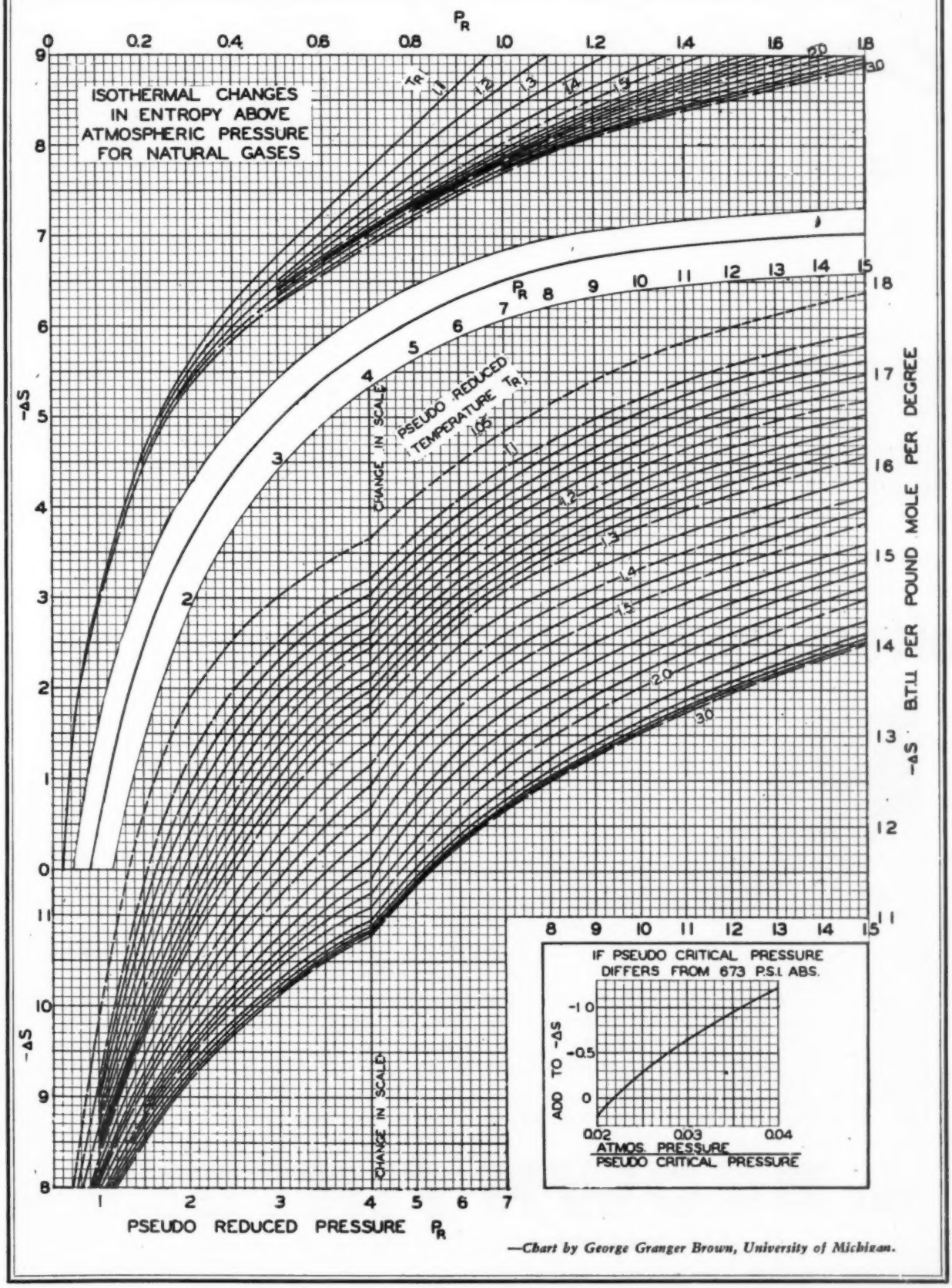
ISOTHERMAL CHANGES IN ENTROPY FOR NATURAL GAS


ISOTHERMAL CHANGES IN ENTROPY ABOVE ATMOSPHERIC PRESSURE FOR NATURAL GASES
P_R
T_R
PSEUDO REDUCED TEMPERATURE T_R
CHANGE IN SCALE
$-\Delta S$
$-\Delta S$ B.T.U. PER POUND MOLE PER DEGREE
PSEUDO REDUCED PRESSURE P_R
IF PSEUDO CRITICAL PRESSURE DIFFERS FROM 673 P.S.I. ABS.
ADD TO $-\Delta S$
ATMOS. PRESSURE / PSEUDO CRITICAL PRESSURE

—Chart by George Granger Brown, University of Michigan.

BROWN FINTUBE'S

Easy to Assemble

GASKETED HEAD SEAL

offers many outstanding advantages

Brown Integrally-Bonded Fintubes are used in all Brown Fintube Heat Exchangers,— are available in Exchangers made by most other manufacturers,— and are ideally suited for many other heating and cooling services. Furnished in plain, "longitudinal," or "cut and twisted" types,— wide range of sizes in low-carbon or special steels. Design assistance furnished gladly.

★ Consisting of two split collars, provided with cap screws, which can be tightened to force the solid ring and gasket against the shoulders of "positioning fittings" welded on the shell and fintube—(see view above),— the new head seal on Brown Fintube Sectional Heat Exchangers has won enthusiastic acclaim from operating and maintenance men.

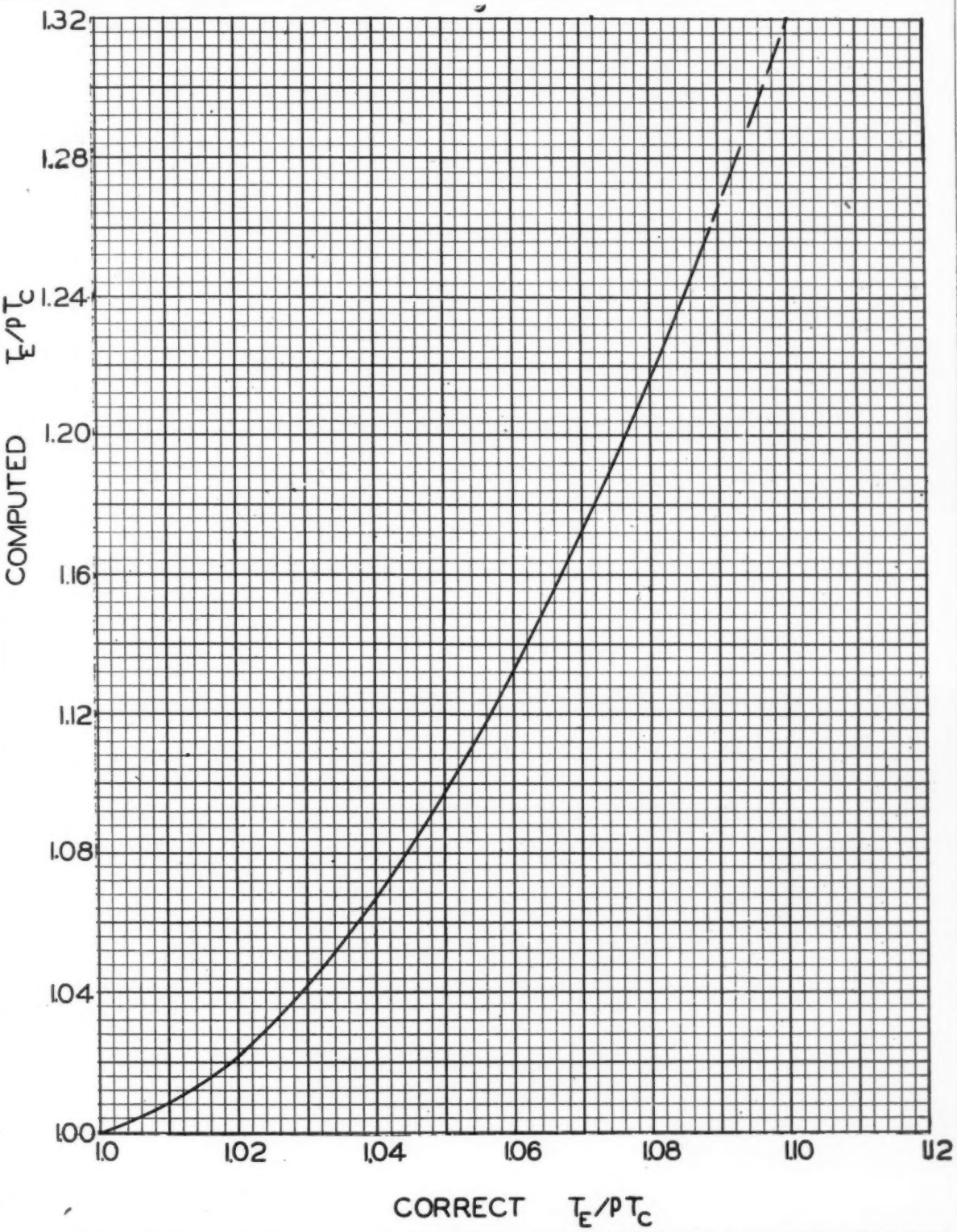
This new seal is easily assembled and disassembled with only a small movement of the cap screws—and using a standard wrench—thus permitting the exchanger sections to be mounted side by side—saving space. It avoids lapped, gland, or ground joints—and since all parts are easily accessible for cleaning, the seal assures positive, tight closure—time after time—free from dirt—and without any outboard stress, or any torsional twisting of either the shell or fintube. The seal holds exceedingly high pressures without "bleeding"— can be used with either composition or metallic gaskets,— and offers many other advantages. But send for Bulletin No. 432. It gives full details about Brown Fintube Sectional Heat Exchangers,— gives dimensions of standard units,— and contains other data of much interest to engineers and operating men.

THE BROWN FINTUBE CO.

125 FILBERT STREET • ELYRIA, OHIO

MANUFACTURERS OF INTEGRALLY BONDED FINTUBES AND FINTUBE HEAT EXCHANGERS

EQUIVALENT AND PSEUDO CRITICAL TEMPERATURE RATIO CORRECTION FOR METHANE

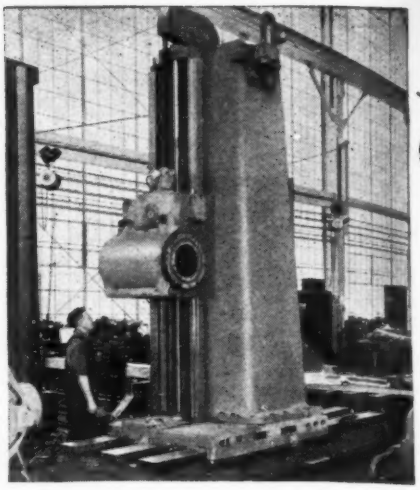


Note: This chart correction for the ratio of equivalent critical temperature to pseudo critical temperature to be used whenever a mixture contains methane. Whenever the mixture contains methane, the computed ratio is not to be used, but rather the correct ratio as read from the computed ratio in this chart.

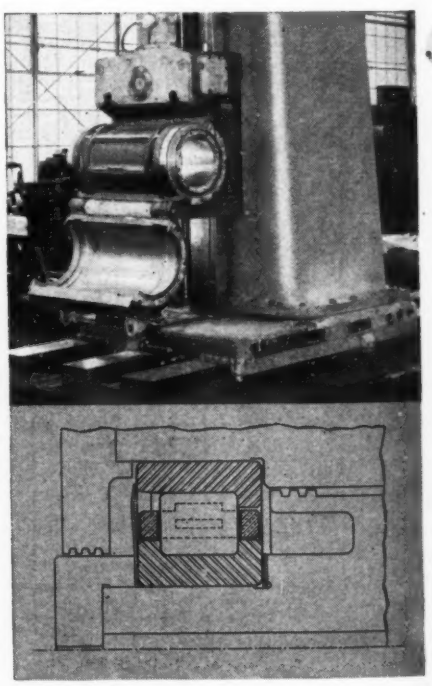
—Chart by George Granger Brown, University of Michigan.

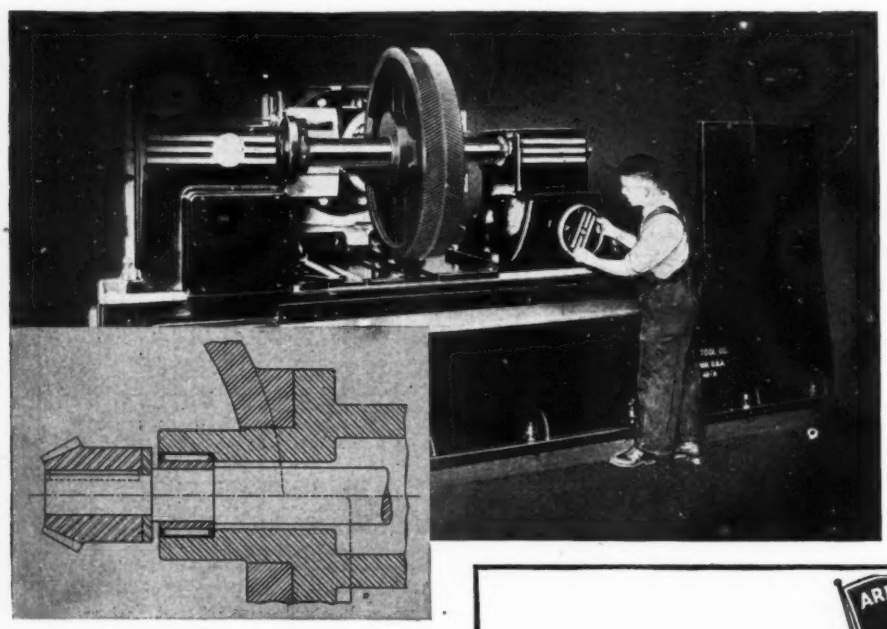
IN THE NEWS
WITH TORRINGTON BEARINGS

TANK BUSTERS must pack the power not only in armament but for locomotion as well. The M-12 shown here which mounts a 155 MM. field gun and designed to have all the speed and mobility of a tank, was among the first of our Army's fleet of tank destroyers. In the compact, efficient power plants of these modern weapons are small, heavy duty Torrington Needle Bearings—used to carry and transmit the heavy loads under the toughest imaginable service conditions. For applications such as automotive transmissions, universals and differentials, the high unit capacity, small size and efficient lubrication of Needle Bearings make them ideal for all radial load applications.



SUPPORT FOR A 24-FOOT BORING BAR is the job of this large end support bearing for a floor type horizontal boring, drilling and milling machine photographed in the shops of Giddings & Lewis Machine Tool Company. Supporting this huge shaft in the housing shown open in the close-up photo (below) are two special 18-inch O. D. radial roller bearings supplied by Torrington's Bantam Bearings Division. These bearings illustrated in the cross-section illustrate the type of service Torrington is equipped to render in the design and manufacture of special bearings to meet the unusual and out-of-the-ordinary bearing requirements. Why not TURN TO TORRINGTON for specialized assistance on your next bearing problem?





GEARS FOR TURBINES up to 4 feet in diameter and 20-inch face width are processed on this Michigan Tool Company's gear finishing machine. Several key points in the infeed mechanism are mounted on Torrington Needle Bearings to insure smooth, friction-less operation. Typical is the application of a Torrington Type DC Needle Bearing (with hardened inner race) on the hand operated infeed shaft shown in the cross-section.

ARMY E NAVY

TORRINGTON BEARINGS

STRAIGHT ROLLER · TAPERED ROLLER · NEEDLE · BALL

THE TORRINGTON COMPANY · BANTAM BEARINGS DIVISION

SOUTH BEND 21, INDIANA

Concepts and Methods of Cathodic Protection

Part 2

by J. M. Pearson
Susquehanna Pipe Line Company

IF, in this same example the polarizing current is increased enough, the cathode reaction eventually uses up all the oxygen that reaches the surface, then proceeds to reduce the minute film that formed over the cathode area. This can be observed by the great reduction of the film resistance, and by the abrupt change of the slope of the hydrogen overvoltage curve that occurs when hydrogen is discharged on the erstwhile cathodes as well as at the previously-reversed anode areas. When the electrode has been reduced to this condition, its potential tends away from the noble direction, and becomes more negative. Under this treatment, the metal is quite activated and if the cathodic protection circuit is shut down it may discharge at a high rate to a remote cathode. This condition also merits more quantitative observation under field conditions. Under either circumstance present evidence points to the fact that cathodic polarization that is initially sufficient to stop corrosion results in changes of the environment, which reduce the local cell action and therefore reduce the polarizing current needed to maintain protection.

It is accordingly desirable that careful quantitative data be taken so that reliable allowance can be made for the expected reduction of the polarizing current. It is equally desirable that observers measure any condition that would seem to be contrary, i.e. one in which the effect of the cathodic polarization seemed to increase the local action current.

Electrical Instruments

The above discussion indicates the desirability of making measurements that will accurately determine the relation of the potential of a buried structure to the polarizing current, either by measurement of the IR drops so that proper corrections can be made, or by otherwise removing the IR drops from the observations. These corrections are especially necessary on buried structures because of the inhomogeneity of the soil and because of the variability of the resistances at the metal surface. The variability of the latter is pronounced either for bare or coated structures.

It is also clear that it is desirable to evolve field methods that are rapid as well as reliable so that it is economically feasible to take sufficient data on each problem. Arguments have been presented that it may be better to install all cathodic protection units of the maximum size indicated by the worst conditions, than to spend more time on the individual designs in order to save on the installations. As the current requirements per unit area vary over a ratio of 3 to 1 normally, and at times vary by 50 to 1, one answer to the argument may be the possibility of substantial energy savings. Another answer is that stray currents from cathodic protection units are a real menace to other properties, which will suffer losses directly proportional to the amount of stray current they discharge to earth.

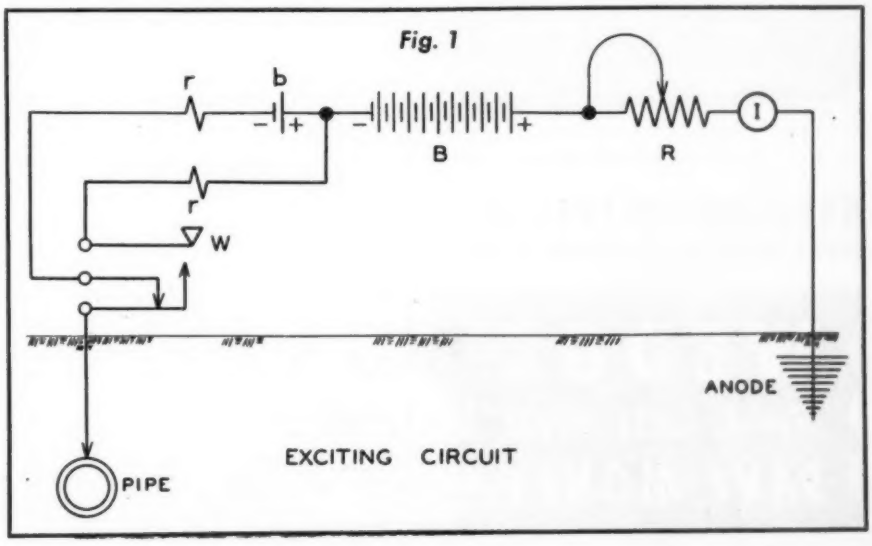
The basic problem of instruments to measure the polarization of a buried structure hinges upon the fact that the polarization itself is a function of the applied current. This implies methods that are independent of, or accurately account for, the presence of the exciting current. In the laboratory it is possible to take advantage of the slowly changing quality of the polarization potentials by the use of commutation. This principle, given a useful embodiment by A. Hickling[2] and others, depends upon suddenly interrupting the exciting current, making the observation in a few thousandths of a second, and then re-establishing the current before the polarized potential has drifted to any significant degree. The short interruption also makes the average and the peak currents more approximately equal. In the field, this principle cannot be conveniently used because of the very size of the electric circuits involved, and because the exciting current may not be the only one that needs commutation. The physical size of the exciting circuits in the field results in time constants of the order of a few tenths of a second, which means that the transient condition is more persistent than some of the elements of the polarized potential. The gradients due to currents other than the exciting current are usually to be accounted for only by measurement, and it is clearly impossible to commutate them.

The field problem of measurement consists of the measurement of exciting current, correction for the significant strays, and of measurement of the potential of the buried structure free of superposed IR drops in the soil, structure coating, and in any film on the metal surface.

The usual practical form of the reference half cell is the copper sulphate electrode. This electrode has received a great deal of competent attention, some

[2]A. Hickling, *Transactions, Faraday Society*, Vol. 33, p. 1540 (1937).

Fig. 1



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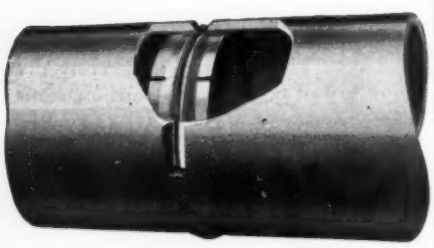

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of the most recent data of great practical value being due to Scott Ewing[3]. From these studies it is apparent copper sulphate electrodes of the saturated type are non-polarizable for practical uses only if the current density at the copper is less than 100 microamperes per square centimeter. This immediately gives the relation between the size of the electrode that should be used and the amount of current that the observing apparatus may reasonably draw.

Because of this limitation, and because of the convenience and portability of small reference cells, it is advantageous to use observing circuits of high resistance. Many embodiments of the vacuum tube voltmeter are in use for this purpose, some of them capable of retaining an accurate calibration over a long time and over a wide range of battery voltages. One of them that derives its stability by application of the inverse feed-back principle, and which is satisfactory for field use has been described[4].

The essential point to be understood is that whatever method of measurement is used, reproducible results will be achieved only if the observing circuit losses are made negligible or are corrected for, and if the instruments are corrected for calibration errors.

Let us consider the errors in the observing circuit when measuring the electrode potential of a segment of a buried pipe line. The term segment is used because the observing circuit usually terminates in a half cell, which is placed directly over the pipe on top of the ground. A simple integration of the effect on the potential at the observation point due to the pipe line below shows that the greatest part of the total potential is contributed by a relatively short section of the pipe immediately below the observation point. Approximately 90 per cent of the potential is determined by a segment of the line four times as long as the depth to the centerline, if the earth is uniform and the pipe buried deeply compared to its diameter. This consequence of the proximity of the observing circuit terminal leads to several interesting questions: If the potential due to more of the line is to be observed, it is necessary to locate the reference cell laterally at a distance great enough so that the desired length of the line will subtend at the reference point an angle of about 120°. It is thus evident that the reference point immediately above the line (if the line is bare) "observes" 12 ft. of line, if the depth to centerline is 3 ft.

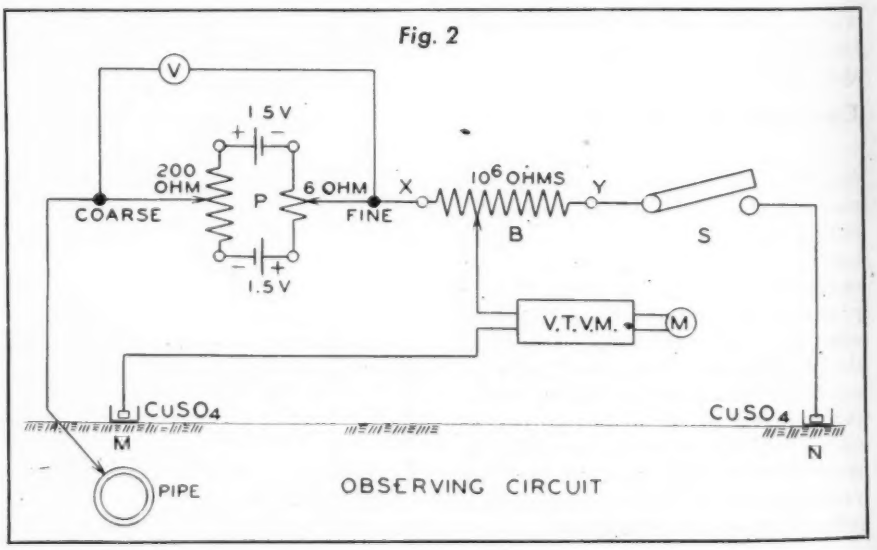
The consequence of this is that the segment observed may be predominately either cathode or anode, and the local action current from it through the earth will affect the observation in the same way that a stray current would. The presence of such a condition can be detected and the gradient measured by use of an earth current meter, of which there are several forms available. Only by such measurements can the potential of the pipe segment under observation be accurately determined as related to the impressed polarizing current. For cathodic protection measurements this is not always necessary, as the problem usually amounts to determining how many amperes are needed at a given anode to polarize the given line segment; and the local action current simply shifts the "zero" of the observations, which are complete when they are ample to show the desired break in the E- log I relation.

The considerations of the above paragraph, however, are based upon the presumption of a bare line, and such is not always the case. The line may be intentionally coated, or it may be possessed

[3]Scott Ewing, "The Copper-Copper Sulphate Half-Cell for Measuring Potentials in the Earth." *A.G.A. Technical Section*, April 17, 1939.

[4]John M. Pearson, "Null Methods Applied to Corrosion Measurements." *Transactions, The Electrochemical Society*, 81, p. 485, 1942.

Fig. 2



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of a high resistance surface film. Either condition will tend to extend the length of the "observed" line segment. A similar effect is produced by underlying beds of high resistance rock. Resistance of the earth and immediate surroundings of the buried line introduce into the observing circuit a coupling resistance that is mutual with the exciting circuit. Fortunately, in the vicinity of the line, the current interchange with the earth is substantially radial regardless of the remote paths followed by the flow lines. It is thus that the local action current component to remote sections flows through nearly the same mutual resistance (per unit length) as that followed by the component of the anode current reaching the observed section. This makes it feasible to correct the exciting current zero by the amount of current needed to reduce the net superposed gradients to zero, if it is desirable to reduce the readings to a basis of true total current. (Naturally, to determine the real current density, the inhomogeneities in the resistance of the earth and coating are involved. Accuracy to within 5 per cent is about the best to be expected for this determination).

The crux of the problem of measurement of the polarization potential of any buried structure lies in the fact that the polarization is a function of the current density, and hence must be measured in the presence of the exciting current. The fact that the polarization is a slowly changing function of the current makes it convenient to use small increments of the current to correct for the IR drop in the coupling resistance between observing and exciting circuits. Thus a change of 10 per cent of the exciting current makes precisely 10 per cent change in the IR drops, but a comparatively negligible change in the value of the polarization.

How this is made useful is illustrated in elementary form in Figs. 1 and 2. The principles involved are treated more rigorously and the errors are calculated in a previous publication[4].

In Fig. 1 is shown the exciting circuit. The batteries B and b supply the exciting current. The resistance R controls the current that is measured by the ammeter I. The switch W when thrown in the upper position includes the battery b in series with the battery B. In the lower position, b is cut out of the circuit. Switch W is of the make-before-break variety so as not to interrupt the exciting current. The small resistance r limits the short circuit current while the switch is thrown, making a smooth transition from one value of the exciting current to the next. If the voltage of b is exactly one-tenth of the total voltage in the exciting circuit, throwing switch W down will reduce the exciting current exactly 10 per cent of its original value, and this will be true for any adjustment of R whatever. The change in current, in amperes, which results from the operation of the switch W, we will refer to as the "current increment." It is understood that the current increment will be of the order of 10 per cent, which, for practical purposes, results in negligible effect on the cathodic polarization of a buried structure. (Any question on this point should be determined experimentally, and the increment made smaller if necessary.)

One of the chief sources of error in making measurements by use of current increments lies in the difficulty of accurately measuring the increment itself. If an ammeter as I is accurate to 1/2 per cent, then a 10 per cent increment can be observed with a precision of only 5 per cent, which is poor enough to be unsatisfactory. If high precision instruments are used, they become unwieldy in the field and trouble arises from minute variations of the power source. For these reasons it is desirable to make observations that are independent of the exact amount of the increment of current used to determine the IR drops.

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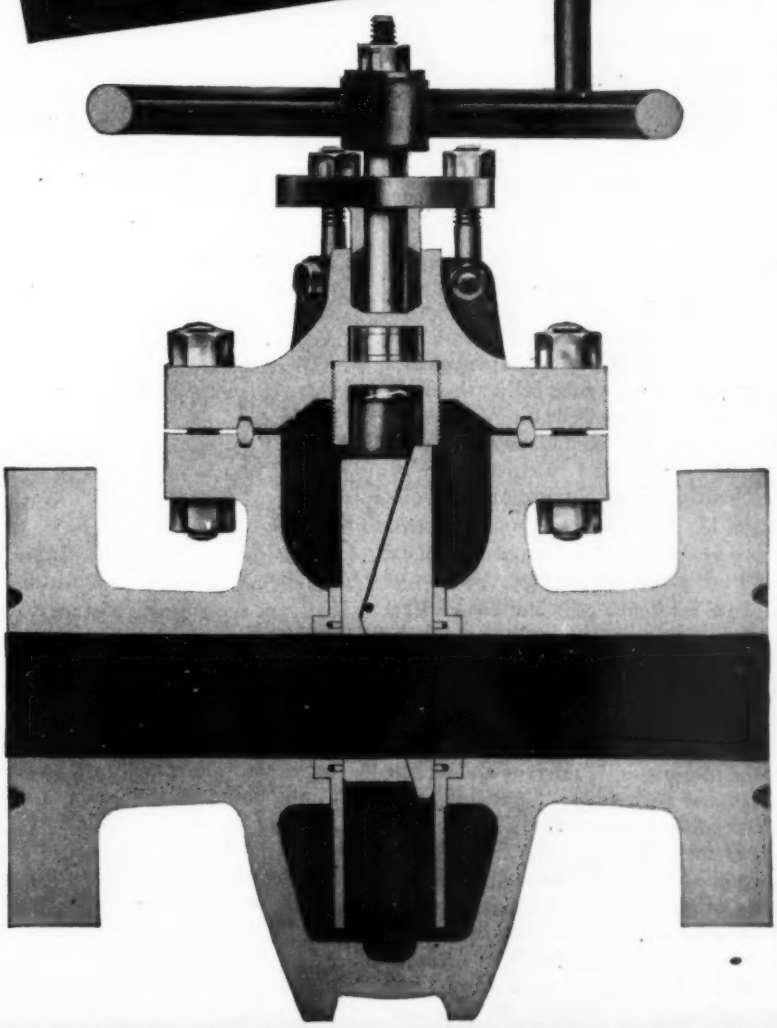

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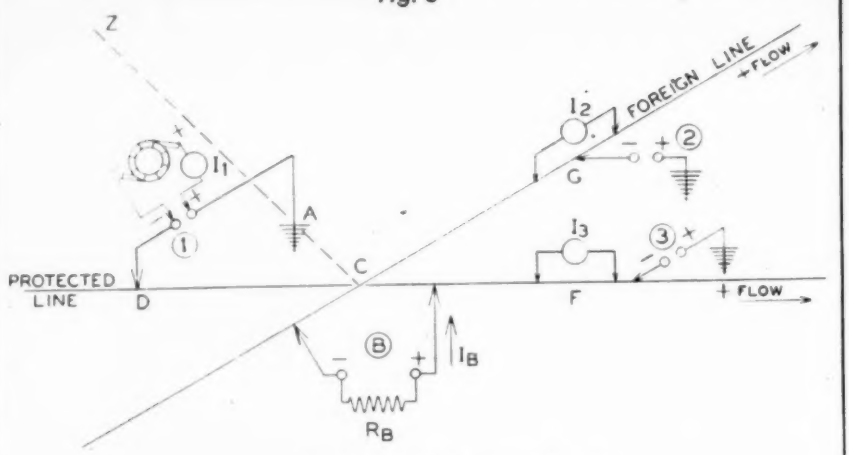
Fig. 3



INTERFERENCE PROBLEM

In Fig. 2 is a schematic drawing of the observing circuit, which will serve two purposes: It can measure the effect of the increment directly, so that it can be used for computing the IR drop correction or it can be used as a null circuit. When properly adjusted to null by use of the current increment, it removes from the observation the component due to the IR drop. The battery-potentiometer circuit P is of low resistance and serves to drive the observing voltmeter V and to supply the backing-out potential for making a null observation. The potentiometer rheostat x-y is of high enough resistance to constitute the majority of the whole circuit resistance including the reference cells, the earth, and the backing-out circuit P. The variable contact B is connected to a direct current vacuum-tube voltmeter VTVM, which drives a second calibrated voltmeter M. Voltmeter V may conveniently be of 0-1 volt range and M of 0-.01 or 0-.10 volt range for copper sulphate reference cells and buried steel structures. The input resistance of the VTVM should in turn be incomparably high compared to the potentiometer x-y, so that negligible current is drawn.

For making observations of the effect of the increment of current the circuit is operated with switch S open. Because of the relative values of the resistances, it will be clear that with S open the position of B is immaterial to the sensitivity of the VTVM to the increments of IR drop produced by the increment of current. The value of V is adjusted by use of P so that M reads zero. Then the reading of V includes the polarization potential, if any, plus the IR drop included between the reference cell M and the pipe. If now switch W is manipulated in Fig. 1, the effect of the increment of current can be accurately observed on the calibrated low range meter M in Fig. 2. Granted that the value of the current increment is accurately known in the exciting circuit, the mutual resistance in the observing circuit is equal to the increment of potential observed divided by the increment of current producing it. This resistance, in ohms, multiplied by the total exciting current I will then equal the total IR drop included in the reading V. By subtracting it, the observation is corrected to give the electrode potential of the pipe referred to M.

As mentioned, the procedure outlined involves a fundamental liability to a large error, as well as the labor involved in calculating the corrections required. The method may be used if sufficient care is taken, as a check on the null method, which we are about to describe.

If the switch S is closed, the circuit is prepared to make use of the second reference cell N to make readings that may be null with respect to IR drops. Remembering that the resistance of the potentiometer x-y constitutes practically all the circuit resistance, it is clear that closing switch S will not change the potential of x, but will make the potential of y substantially that of the reference cell N. If M and N are identical half cells then the potential difference from y to x will be about the same as the potential difference in the earth from N to the pipe including the electrode potential of the pipe. The small current that flows from y to x produces an IR drop that closely corresponds to the IR drop due to the current flowing to the pipe through the earth. Consequently, with respect to the IR drop, the contact B can be moved to the point on the wire y-x that corresponds to the point M on the earth. At this point, if the switch W is operated the increment of current produced will not disturb in any way the deflection of the meter M. As this is a resistance balance, it is clear that with the contact B so located, any IR drop in the soil or at the pipe surface will be balanced by the corresponding IR drop from x to B, and the adjustment of P to make M read zero will require a backing-out potential only for the electrode potential of the pipe. We have thus substituted a circuit adjustment for a calculation, and the observation is made in two steps to yield a direct measurement of the desired potential. The first step is made by adjusting the bridge balance at B so that the current increment produces no change in the deflection of M, whatever deflection it may have. The second step is to reduce the deflection of M to zero by adjusting P so that V will equal the electrode potential to be measured.

Because adjustment of the observing circuit nulls out the IR drops in earth, pipe coating, and surface film, it is no longer necessary to compute and subtract them. Consequently there is no need for any special precision in determining the amount of the current increment. As mentioned, however, it must be small enough so that it has negligible effect on the polarization potential. For buried steel electrodes a 10 per cent increment is practical and satisfactory.

The use of this null method is, however, not free from sources of error, and its practical application involves consideration of questions of sensitivity, etc. In Fig. 2, the closing of switch S causes a current to flow through x-y from the cell N to the pipe. The value of this current and the size of cell N must be considered lest N be polarized an objectionable amount.

If the IR drop between M and the pipe is unusually large, it is clear that the null adjustment for the IR drop will require that B be located near to the y end of x-y. If B were put at the point y, the VTVM would be shunted by the earth between M and N and by the cells themselves. The effect of this is to reduce the sensitivity of the VTVM to adjustment of the backing-out circuit P. Thus it is desirable so to arrange the cells M and N that the IR drop between M and N is comparable to that between the pipe and M. In this way the null system is not made too insensitive to the backing-out adjustment.

Because of the logarithmic variation of potential with radius, it is necessary to keep the radial distance of M equal to or less than the geometric mean of the radial distance of N and the electrical radius of the pipe. (The electrical radius of the pipe is the radius it would have to be shrunk to in order that its resistance to earth per unit length without an insulating film would be the same as it is with the film, but of normal size.) As the electrical radius of a bare 6-in. pipe may often be 2 or 3 in., and of a coated pipe perhaps only a small fraction of an inch, it is clear

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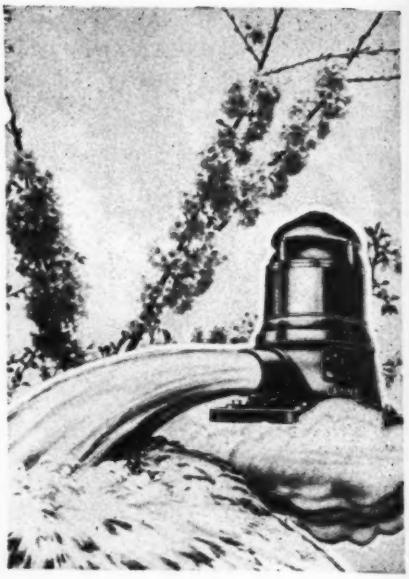

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that if M is directly over a line buried 30 in., N should be about 30 ft. offside. Sometimes it is necessary to locate N near the polarizing anode, in order to obtain a sufficient current in the x-y bridge, if M is put any distance from the pipe line. With M directly over the pipe, the potential it observes is 90 per cent due to the 10 ft. of line immediately under it, if the centerline depth is 30 in. and the line bare and free of surface resistance. The effect of surface resistance and of coating is to increase the amount of line observed by M, so the above may be taken as a lower limit.

These considerations simply serve to point out limitations of a single observation on such a structure as a pipe line. On a less extended structure such as the bottom of a single tank, the reference point M can be made to observe the whole object by moving it away three or four tank diameters. In general, it is practical to assume that the reference cell M observes the integrated effect of any limited object when the dimensions of that object subtend an angle of 60° or less at M.

The greatest sensitivity of the circuit to the D.C. balance is obtained when M is located so as to include the least IR drop consistent with observing the object of interest, while N is located to pick up a comparatively high IR drop. Thus, if a tank bottom is to be observed, M might be spaced from the side of the tank that is remote from the anode. N may be placed near to the anode to make the VTVM sensitive to the D.C. adjustment after balancing the bridge for IR drop.

Other errors that can occur in the use of the null circuit result from inequality of the reference cells M and N. The exact analysis of errors from this source is given in detail in the Electrochemical Society paper[4], and indicate that reasonable care is needed to make M and N identical in their half cell potential. When copper sulphate is used, a difference up to 10 mv. can be tolerated. This means for instance, that one should not be left in the sun, the other in the shade. Also the size of the copper in N should be so large that the bridge current does not exceed 100 microamperes per square centimeter.[2]

The exciting current used to run the polarization curve on a pipe line can produce enough products of reduction during a run to make a semi-permanent change in the electrode potential of the line. The null circuit is especially convenient in this respect, as the data can be quickly run, before sufficient ampere-hours have passed to cause an objectionable drift.

As mentioned, if there are local action currents or stray currents flowing from the line to earth at a point of observation, they, in effect, shift the zero point on the plot of the E— log I relation. In order to obtain the true line potential at that point, the effects of these gradients must be accounted for. If, however, the observation is principally intended to determine the protective current required from a given anode the shift in the zero will not affect the amount of current determined from the break in the curve.

Portable radio telephones licensed in the geophysical service are convenient accessories when observations are made at considerable distance from the current-controlling circuit.

Other instruments that are very useful in cathodic protection studies are identical with those that are used for stray current problems, and are used the same way. Current measuring instruments should be of high quality and frequently calibrated. Millivoltmeters to measure the current in a buried line should likewise be suitable, and must be corrected for lead and contact resistance as well. Where better than relative values of the line current are to be obtained, it is necessary to calibrate the resistance of the segment of the buried line and correct this calibration for the part of the calibrating current that bypasses through the earth. Suitable in-

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Fig. 16
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Fig. 1640
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Fig. 1430
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Fig. 1938
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struments and methods have been detailed before[5] [6] and will not be considered in detail here. In the following section, which deals with the problems of measurement in solving cases of cathodic interference, we will assume that instruments used are corrected for errors introduced by the external circuit and for calibration. It is more satisfactory to pay for and maintain high quality instruments than to repeat whole series of observations that are useless or misleading because they are inaccurate. An electrical survey should be subject to closure in the same sense as a geographical survey, i.e. the prime requisite of a set of data is self-consistency. The next most desirable property of a set of data is its standardization. It is most convenient if everyone uses the same sizes of electrical units.

One of the difficulties with the general application of cathodic protection lies in the variation of the required protective current from one place to the next. There is evidence that corrosion due to bacterial action may be controlled by cathodic polarization, but that current densities a whole order of magnitude higher may be required. This particular field deserves immediate and thorough investigation, especially to determine whether the increase of pH may not result in such a lowering of the local cell current that less protective current is required.

Cathodic Interference

When cathodic protection is used on an extensive buried structure, any neighboring structure is exposed to the possibility of damage by electrolysis. The effect on the foreign property is to increase the weight loss from the pits in its surface in direct proportion to the ampere-hour discharge to earth. The high resistance cathode film, which affects the distribution of the external current between the anodes and cathodes in cathodic protection, has the identical effect in the distribution of current discharged to the earth. The anode current loss is increased more in proportion per unit area than the cathode gain is decreased. It is not surprising that the owners of affected property, cognizant of the possibilities, object to cathodic protection installations that leave parts of their structures exposed to electrolytic corrosion. The handling of the problem is technically similar to the handling of problems of any stray current, with the exception that each problem at its beginning presents one more degree of freedom to the engineer. Whereas stray currents from

[5] J. M. Pearson, "Electrical Instruments Applied to the Study of Pipe Line Corrosion" *A.P.I. Proceedings*, Vol. 16, IV, pp. 75-80, 1935.

[6] J. M. Pearson, "Electrical Instruments and Measurements in the Solution of Electrolysis Problems," report to the fourth Bureau of Standards Corrosion Conference, 1937.

electric railways usually are dealt with from the standpoint of disposition only, the cathodic protection engineer has the privilege of making an intelligent selection of his sources of earth-currents, so that the problem of their control on foreign structures is simplified. The best use of this opportunity implies a degree of cooperation between those responsible for the several structures involved.

In the following we will treat the problem of cooperative cathodic protection installations from the standpoint of the measurements and the method of design.

The simplest case is that in which both parties desire cathodic protection. This is most easily treated by bonding the structures solidly together, and designing the installation as though they were both one structure. In this manner any local action current that results from the bond must be controlled in order to reach the protective current, and as they exist when the polarization measurements are made they are accounted for. When structures of dissimilar metals are to be bonded and protected, the same procedure may be followed, although if the local action current is excessive it may be better to drain the more anodic structure and bond the less anodic one to it with a current limiting resistance.

In order to be clear, it may be wise to review some of the definitions of terms that will be used in dealing with the electrical networks of buried structures.

A solid bond, or a cold bond is a connection between two structures, whose resistance is a tenth or less of the internal resistance between the structures.

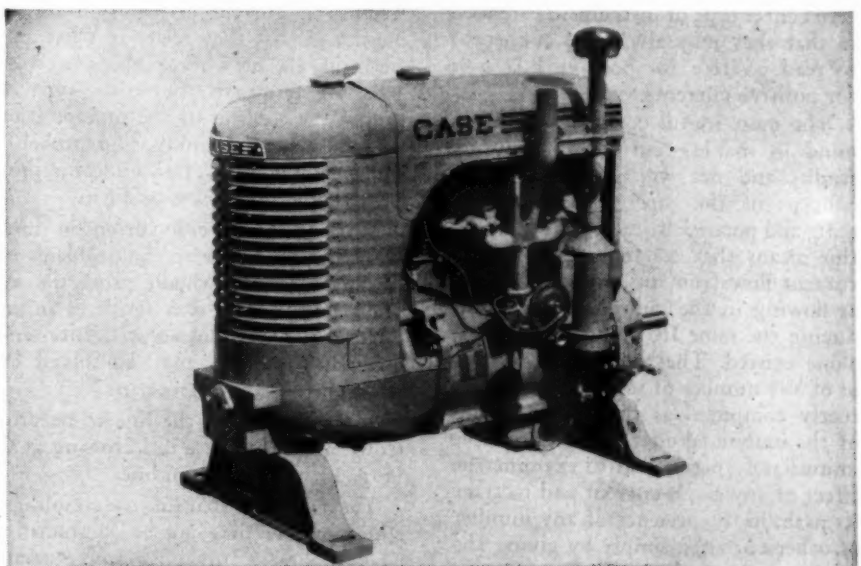
A resistance bond is bond similarly connected, but whose resistance is large enough to be a controlling factor in the current flow.

The internal resistance between any two points whatever is the change in P.D. between them per ampere caused to flow from one to the other. The sign is always positive and the resistance is expressed in ohms. (Note the implication of the word "change," i.e. current can be caused to flow in an external connection by either the internal e.m.f. or by an external generator, or both, and the change per ampere at the terminals will be the same.)

When such a test current is caused to flow into any pair of terminals, all other pairs of terminals in the same network will exhibit a change in potential. If the change of P.D. at terminal pair b is divided by the test current in amperes at terminal a, the ratio is in ohms and is defined as the mutual or as the coupling resistance. It is conventional to use a two figure subscript to represent internal and mutual resistances, the first subscript standing for the terminals where the P.D. change was observed, the second subscript representing the terminals to which current was applied. Thus $R_{b,a}$ means the coupling resistance represented by the change in potential at b divided by the test current at a. In linear networks $R_{b,a} = R_{a,b}$; $R_{a,a}$ is the internal resistance at a, etc.

It is customary to label each pair of terminals with plus and minus signs, selected either for convenience or at random. It is necessary to adhere to the signs, once they are chosen, to avoid errors in signs in the calculations. When a given pair of terminals have been labeled positive and negative, then all P.D.'s are measured with the voltmeter connected according to the label. If the voltmeter reads reversed, the data is recorded with a negative sign. The same holds for readings of changes of voltage due to increments of current. An increase in the value of a positive reading is a positive increment, whereas an increase in the value of a negative reading is a negative increment, etc.

When a test current is caused to flow from one terminal to another, the value of the test current is positive if it produces a positive increment of P.D. at the terminal pair in question. This is the reason that all internal resistances are



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positive, regardless of the signs given the individual terminals of the pair.

However, when mutual or coupling resistances are measured a positive current at a may produce either a positive or negative increment of P.D. at b, so that $R_{b,a}$ may be either positive or negative. It is important to keep these signs straight.

In regard to the flow of current in a buried structure, it is convenient to designate one direction as the direction of positive current flow. Data on current flow and on increments of current flow are then recorded with the appropriate sign, depending on their direction. Fewer errors are encountered if zero center type of instruments are used so that they may always be connected to read positive for positive P.D.'s or for positive currents.

The most useful concept to keep in mind in making current distribution studies and net work analyses is the concept of the superposition of currents and potentials. As explained above this means that we may think of the current flow from any source whatever as flowing in the same paths and producing the same IR drops as though it alone existed. The total effect of two or of any number of sources can be correctly computed as the algebraic sum of the individual effects. This principle immediately permits us to examine the effect of any given current and to trace its path, in the presence of any number of other currents, simply by giving the current to be studied a label to identify it. For direct current it is convenient to label a given current by interrupting it, and observing the increments of current and potentials at all interesting points. (In the case of a polarizing current, interruption affects the polarization so that the label would consist of an increment of current small enough to have negligible effect on the polarization). Where current paths are being studied and polarization is at the moment uninteresting, it is sometimes convenient to boost the test current several-fold, to obtain higher increments of IR drop in coupling resistances, internal resistances, etc. The excess current will undoubtedly affect polarization but the current distribution for the test current is independent of the polarization potentials, so that the correct result is still obtained and the accuracy improved.

It is thus understood that when we want to determine the current flow in a structure at a certain point, which results from current applied, say, to an anode elsewhere, we will connect a millivoltmeter to the structure, calibrate the span used for IR drops, apply corrections for the lead resistance and for calibration, and record the *change* in observed current per ampere *change* in the test current at the anode. If the anode current is changed by interrupting it, the whole value of the anode current would be recorded as the change. Likewise for couplings the changes in potential are recorded for the changes in current at the test terminals.

In the above paragraphs, which are intended to show the utility of the concept of superposition of electric fields, we wandered about in the discussion between the intensive and the extensive aspects of the problem. Network constants are extensive in that they can be accurately measured and put to use with no need of detailed information of the internal structure of the network. Studies of current distribution are intensive in that they relate to what goes on inside the network, perhaps between pairs of terminals. In either type of study, the concept of the superposition of fields is enlightening, and probably indispensable to a clear understanding of cathodic protection problems.

With the above conventions in mind we will return now to the problems of specific cases of cathodic protection of one structure that may result in an interference with another structure, and how the problems may be solved by straight-forward engineering.

Suppose we own the line to be protected and that there is a crossing at C (Fig. 3) with a foreign line.

The owners of that line use couplings, which may or may not be conducting. Their policy is to avoid any current flow whatever on their line, and they are satisfied with the corrosion conditions on their property. For this situation there is only one straight-forward solution, namely to confine the field of the cathodic protection current strictly to the right-of-way of the protected line. This can be done by the use of a distributed anode such that the current is fed to the earth at closely spaced intervals along the line, and so balanced electrically that the current flow from each anode is absorbed by the immediately adjacent segment of line. At the crossing itself, the line should be protected by insulation with a thick coating over sufficient length (10 to 20 times the lateral spacing of the distributed anode) so that the foreign line will pass through an electrically undisturbed crossing. G. I. Rhodes[7] has developed the use of distributed anodes and we need not go into the engineering details again here. Methods of examination described below will serve, however, to check the freedom of the foreign structure from strays and to examine conditions at the crossing.

Suppose now, that the owners of the foreign line feel they do not need cathodic protection, but are willing to cooperate by permitting us to drain their line through a bond to protect it from strays. Their requirements are simply that their line shall in no way be caused to discharge current to the earth as a result of our installation; and they do not expect to be required to pay for any incidental cathodic protection they may receive.

This is the most usual situation, and is similar to the problem of protection of two or more structures that require perhaps different degrees of protection. It is likewise similar to the problem of simultaneously protecting two structures of different metals with one installation.

Although we will use a simple crossing of two lines as an example, those who follow the principles will see how they will work for multiple crossings and for interference involving more than one anode.

In Fig. 3 the horizontal line represents the pipe line to be protected. The anode is at A and the drain point at D. The wires terminating at A and D are labeled plus and minus, respectively, and are designated as terminal pair No. 1. The source of polarizing current will be connected to these terminals. At any other point F on the protected line is another pair of terminals, say No. 3, with the negative side chosen on the line and the positive side chosen as a ground stake above the line. Also at 3 is shown a millivoltmeter set-up corrected and calibrated to read the true line current in amperes I_3. Position F is generalized, there actually being many of them selected to give a good picture of the conditions distributed along the line. We can use odd numbers for the terminals on the protected line and even numbers for similar terminals as at G, distributed over the foreign line.

At the crossing C we will locate terminal B, assigning the negative side to the foreign structure, which is shown as the diagonal line. The positive side is the protected line at the crossing.

The problem is to locate anode A so that satisfactory protection is achieved on our line while at the same time a minimum of drainage will be needed to avoid damage to the foreign line. If the optimum location of A is impractical, more drainage at B will be required, and the cost of operation made higher. In this case the best compromise must be sought. Locations of the anode A for which drainage at B will not suffice to protect the foreign line must naturally be ruled out.

EDITOR'S NOTE: This article will be continued in an early issue of the *Petroleum Engineer*.

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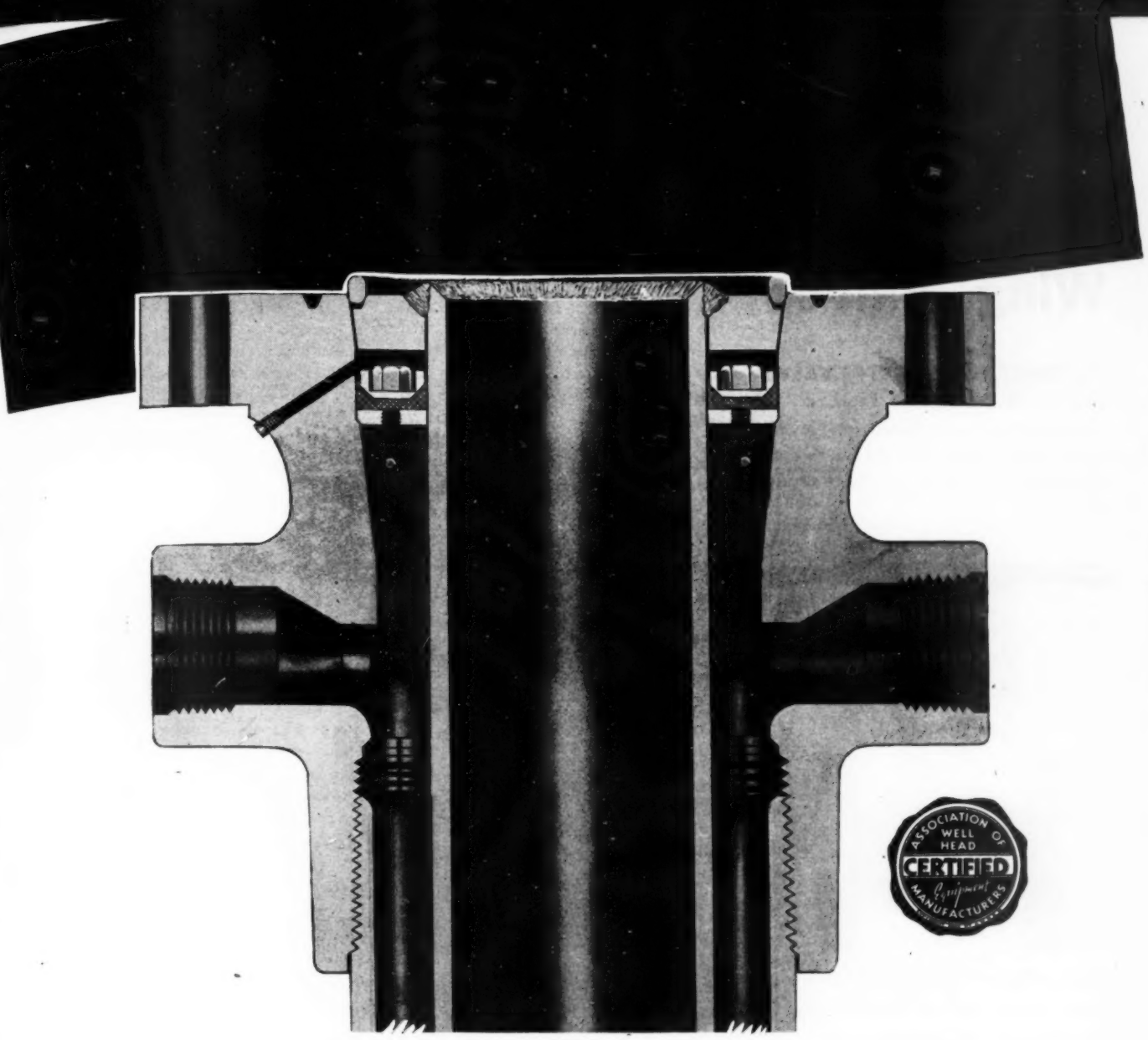
[7] G. I. Rhodes, U.S. Patent 1,962,696, and "Two Unusual Installations of Cathodic Protection to Pipe Lines," *A.P.I. Proceedings*, Vol. 17, pp. 21-32, 1936.



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TULSA **OKLAHOMA**

Running Tour

WITH MEN IN THE INDUSTRY

CLAUDE C. PARSONS, on leave from the Halliburton Oil Well Cementing Company of which he is vice president, has been promoted to be director of the division of materials in PAW. He has been assistant director since the first of the year. Early in his career Parsons was an employee of Magnolia Petroleum Company and during World War I was a lieutenant in the Air Corps. His knowledge of the oil business was gained through 25 years' experience in dealing with materials, equipment, and operations. Parsons succeeds FRANK A. WATTS, who resigned to return to his post as purchasing agent for the Humble Oil and Refining Company. Except for four months, when he worked for Union Oil Company of California, Watts has been with the Humble company since 1919.

JOSEPH H. RUSSELL has been elected to the position of vice president of Gulf Oil Corporation and of Gulf Refining Company. A graduate of Texas University, Russell was associated with Stone and Webster until he went to Gulf Oil in 1921. He has advanced steadily in the 23 years of service with the company.

ROBERT B. MITCHELL has become associated as a partner with Foran, Boatright and Dixon, consulting petroleum and natural gas engineers. Mitchell, a geologist of note, will have his headquarters in the firm's offices, Second National Bank Building, Houston, Texas.

PAUL F. BARNHART has been promoted to general manager of drilling, production, and engineering operations of the firm of Frank and George Frankel, Houston, Texas. Barnhart joined the oil operating company in 1942, after resigning as engineer and assistant production manager of Barnsdall Oil Company. His association with the Frankel company has been spent in drilling and production operations in fields in Texas, Arkansas, Louisiana, and Mississippi.

ADRIAN MOORE, independent oil operator, resigned as director of production of District 3 of PAW in protest against what he termed "bureaucratic control of the oil industry." He was named to the post about a year ago.

O. D. ROBINSON, president, Republic Oil Company, recently announced numerous changes in that organization's Pittsburgh and Texas City staffs, as well as several changes in its affiliates. Pittsburgh changes are: J. H. TONER, formerly manager of retail sales, has been named assistant to the president. R. R. MASON, previously in charge of the Pittsburgh marketing division, has been appointed to the new post of operations manager. G. M. CANTER, formerly in charge of the Virginia retail area, has been named sales manager.

Changes in the Texas City staff and personnel changes in affiliates of the company are: J. E. KELLEY has been named vice president in charge of refining; C. C. EVANS, superintendent of refinery; W. R. HOLMSTEN, assistant superintendent in charge of operations; E. L. SAUER, president, Duval Gasoline Company; LOUIS KELLER, assistant superintendent in charge of engineering and maintenance; J. E. WESTENBERG, in charge of process engineering; H. E. AMMERMAN, vice president and general superintendent of Duval and Republic Pipe Line Companies; H. K. DIXON, vice president and general manager of Duval Gasoline Company; R. H. ARMSTRONG, purchasing agent; H. W. ANDERSON, manager, marine department; R. W. DAVIS, personnel manager; J. L. TRACY, insurance manager.

FRED G. FELLOWS, formerly refinery superintendent of the Ponca City refinery of the Continental Oil Company from 1929 to 1942, is engaging in private practice as a civil and industrial engineer with offices at 201½ East Grand, Ponca City, Oklahoma. Prior to entering the employ of the Marland Oil Company (now Continental) in 1925 as an engineer, Fellows engaged in civil and hydraulic engineering in Colorado and Wyoming principally in the field of design and construction of municipal, irrigation and water supply projects, bridges and buildings.

PAUL L. GOLDSTROHM and GEORGE M. MUSCHAMP have been elected members of the board of directors of the Brown Instrument Company, Philadelphia, Pennsylvania. Muschamp is vice president in charge of engineering of the Brown company, a division of Minneapolis-Honeywell Regulator Company, and Goldstrohm is vice president in charge of production.

WHY IS A DRILLING RIG LIKE A LIBERTY SHIP?

After starting on a voyage, neither a ship at sea nor a rotary drill on the way to its deep-in-the-earth destination can afford to stop for repairs. Power must not be lost, pressures must be held, shafts kept turning.

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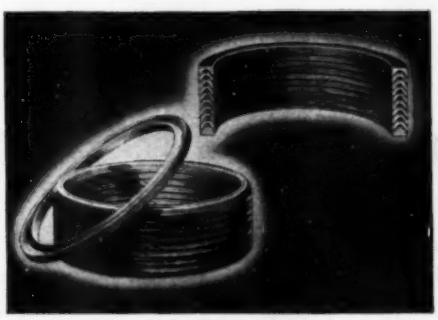
SPECIALLY DESIGNED U. S. Perfected Oil Field Stuffing Box Rings of exclusive design are staff engineered to provide *superior* service and expertly compounded to give *long* service.



AUTOMATIC IN ACTION—U.S. Matchless Packing sets for swivels reduce friction to the minimum. Molded to accurate size, sets have special top and bottom rings for square or bevel seatings.

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"We don't consider our we completed until they are scraped," says an Odessa, Texas operator.

"We figure that our Casing Scraper rental has been all paid for by savings on swabs and packer rubbers."

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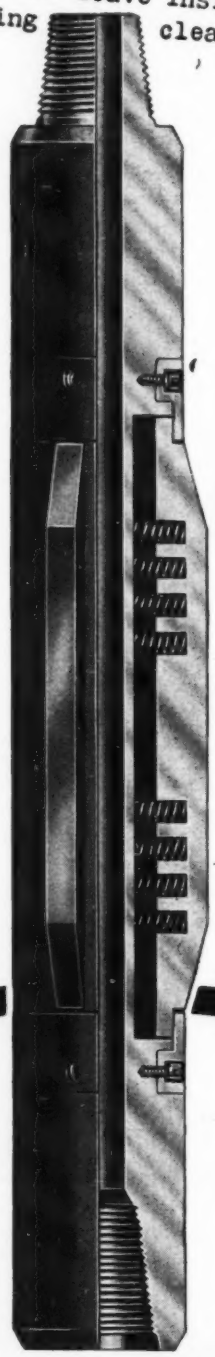

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BAKER ROTARY CASING SCRAPE

LAUGH WITH BARNEY

Mountain Guide: Be careful not to fall here—it's dangerous. But if you do fall, remember to look to the left—you get a wonderful view.

* * *

A young couple asked the parson to marry them immediately following the Sunday morning service. When the time came, the minister arose to say:

"Will those who wish to be united in holy bonds of matrimony please come forward?"

There was a great stir as thirteen women and one man approached the altar.

* * *

The recent shortage brought back a few unrationed booze gags. For instance, there was the gent who mourned:—

"I wish I had my wife back."

"Where is she?" sympathized a friend.

"I swapped her for a bottle of whiskey."

"And now I suppose you realize how much you loved her?"

"Oh, no," the husband moaned. "I'm thirsty again!"

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We heard of a friend who was interviewing a possible maid the other day. Or should I say, being interviewed herself.

"Are you a good cook?"

"Ah doesn't cook," was the reply.

"Oh, I suppose you wash and iron?"

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"I see. Then I suppose you do the cleaning and housework?"

"Ah does not. Ah'm no cleanin' woman."

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"Ah dusts. A little."

P. S. She got the job.

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"I want some grapes for my sick husband. Do you know if any poison has been sprayed on them?"

"No, ma'am. You'll have to get that at the druggist's."

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"Where is that beautiful canary bird you used to have, Mrs. Hoff?" asked Mrs. Pringle. "My, but it used to sing so sweet and nice."

"Oh, we had to sell him," was the reply. "My husband put its cage over the radio one night and it learned static."

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The superintendent called in a roustabout to explain to the gang the purpose of a bolt with a left-handed thread.

This was the bewildered reply. "A bolt with a left-handed thread is a bolt which the tighter it's screwed the looser it gets!"

* * *

He walked up to the store manager, fresh from an encounter with one of those Go Way I'm Busy! type of clerks.

"Isn't there," he said, "a sign in your window that says 'We aim to please'?"

"Yes, that's our motto," was the pleased reply.

"Well, how's about a little time off for some target practice?'

* * *

Mama Kangaroo was in a hurry as she bounced down the road with Baby in her front carriage. But every once in a while she'd have to stop and angrily scratch herself. It impeded progress.

Finally she looked down, came to a sudden stop, yanked Baby Kangaroo out, and began to spank him.

"There," she exclaimed as she put the squalling brat back. "That'll teach you not to eat crackers in bed!"

* * *

Joe: Where do you get your motor accessories?

Tom: Oh, I just honk and smile at 'em and they climb right into my car.

* * *

Here's to the girl who is mine, all mine!
She drinks and she pets
And she smokes cigarettes
And sometimes, I'm told,
She goes out and forgets
That she's mine, all mine!

* * *

Here lies the body of William Brace;
He sure was one fine fella,
He said in his sleep: "I love you, Grace,"
But his wifie's name was Stella.

* * *

The Commanding Officer had had a very hard time with the troops and he said angrily: "No man in the regiment will be given liberty today."

Somewhere a Voice rang out: "Give me liberty or give me death!"

The C.O. turned red and barked: "Who said that?"

The Voice was brief: "Patrick Henry."

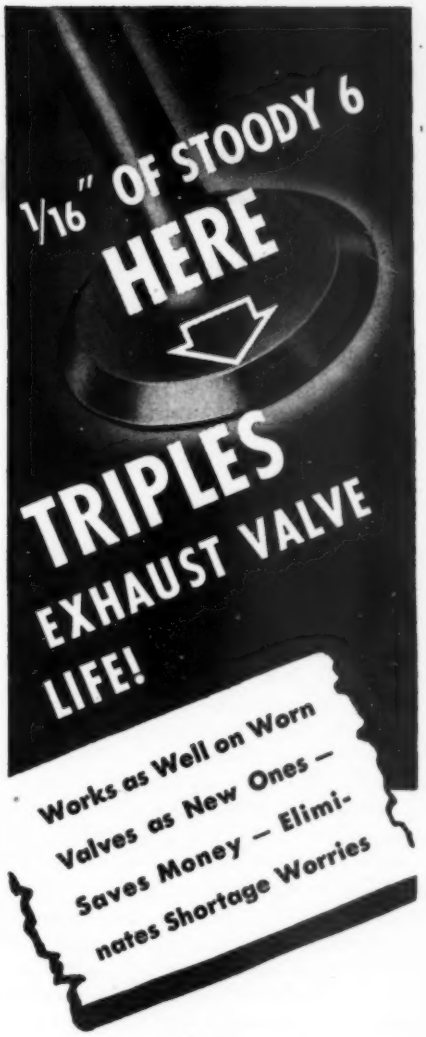
* * *

Private Rastus (at the end of a 20-mile hike under full Army pack): "Sarge, dis ain't what dey calls de standin' ahmy, is it?"

* * *

Gob: What is a buccaneer?

Pal: A buccaneer is an awful price to to pay for corn.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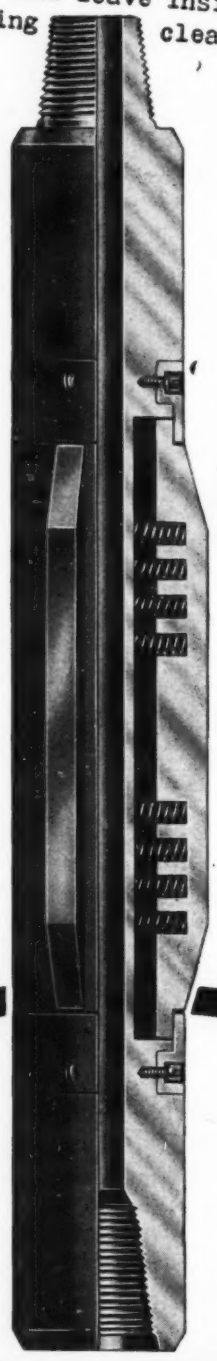

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* * *

He walked up to the store manager, fresh from an encounter with one of those Go Way I'm Busy! type of clerks.

"Isn't there," he said, "a sign in your window that says 'We aim to please'?"

"Yes, that's our motto," was the pleased reply.

"Well, how's about a little time off for some target practice?'

* * *

Mama Kangaroo was in a hurry as she bounced down the road with Baby in her front carriage. But every once in a while she'd have to stop and angrily scratch herself. It impeded progress.

Finally she looked down, came to a sudden stop, yanked Baby Kangaroo out, and began to spank him.

"There," she exclaimed as she put the squalling brat back. "That'll teach you not to eat crackers in bed!"

* * *

Joe: Where do you get your motor accessories?

Tom: Oh, I just honk and smile at 'em and they climb right into my car.

* * *

Here's to the girl who is mine, all mine!
She drinks and she pets
And she smokes cigarettes
And sometimes, I'm told,
She goes out and forgets
That she's mine, all mine!

* * *

Here lies the body of William Brace;
He sure was one fine fella,
He said in his sleep: "I love you, Grace,"
But his wifie's name was Stella.

* * *

The Commanding Officer had had a very hard time with the troops and he said angrily: "No man in the regiment will be given liberty today."

Somewhere a Voice rang out: "Give me liberty or give me death!"

The C.O. turned red and barked: "Who said that?"

The Voice was brief: "Patrick Henry."

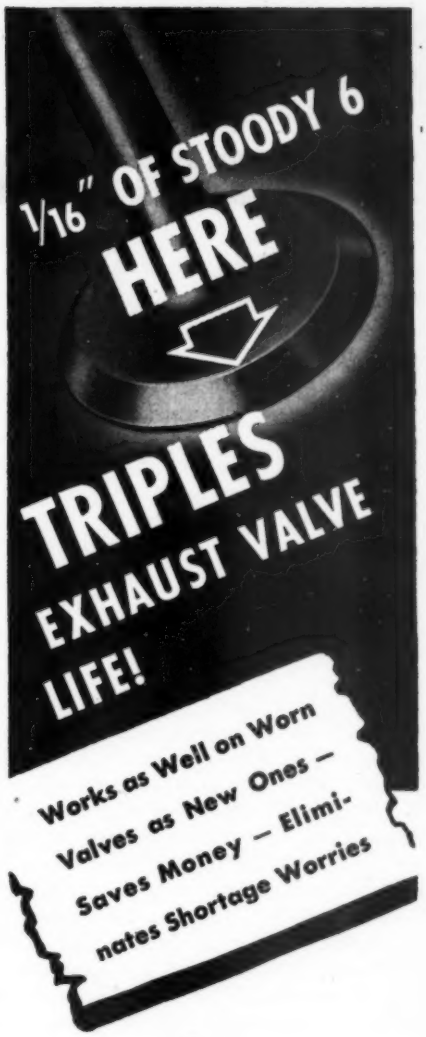
* * *

Private Rastus (at the end of a 20-mile hike under full Army pack): "Sarge, dis ain't what dey calls de standin' ahmy, is it?"

* * *

Gob: What is a buccaneer?

Pal: A buccaneer is an awful price to to pay for corn.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MACHINERY and EQUIPMENT

Aluminum-Bronze Electrode

THE Air Reduction Sales Company announces a new coated aluminum-bronze electrode—Airco No. 10. This new, coated high tensile bronze electrode is a shielded arc electrode, and can also be used as filler rod in carbon arc welding. It will produce welding deposits of great strength and hot ductility, combined with desirable resistance to corrosion, the manufacturer states.

The Airco No. 100 has a universal application in the welding of most bronzes, malleable and cast-iron or steel, it is asserted. In addition, it has other specific applications for which it is especially suited, such as welding manganese bronze conforming to Federal Specifications QQ-B-726b, or Navy Specifications 49-B-3e for marine propellers and other parts where great strength, ductility and corrosion resistance are strict requirements.

The Airco No. 100 can also be used for welding dissimilar metals, such as cast-iron to brass, steel to malleable iron, or the joining of any two metals which are weldable with aluminum-bronze.

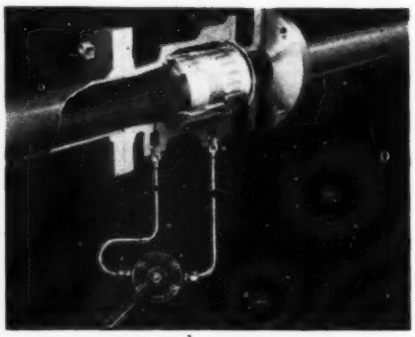
Sizes from 1/8 to 3/16 in. in 14-in. lengths and 1/4 in. in 18-in. lengths are standard stock items. Sizes from 5/16 to 1/2 in. in 18-in. lengths may be procured on special order.

Remote Control Valve

IN contrast to a mechanically operated valve, the Grove Flexflo remote control valve operates by manual or automatic remote control on the hydraulic principle of balanced and unbalanced fluid line pressure. As virtually no external force is required, even a large 24-in. Flexflo valve could be opened or closed as easily as a 1½-in. valve —at the touch of a finger.

Designed for cold fluid service, these new valves are especially suited for handling water, salt water, chemical solutions, oil, gases and air. Due to the fact that they utilize only one non-metallic operating part they are extremely resistant to corrosion and erosion as well as electrolytic action and are automatically self compensating for wear.

Their simplified assembly consists of only four parts: (1) The valve body, (2) the flange head, (3) a slotted pipe-like core with a solid barrier in the center, and (4) a cylindrical flexible tube. This resilient tube is stretched tightly over the core. Both the tube and core slip into the valve body as a unit and are firmly held in place by the bolted flange head. The flanged end of the tube serves as a leak-proof gasket sealing off an encircling pressure chamber from



the flow stream. Existing fluid pressure in the line forces the tube to expand fully against the inner wall surface of the encasing valve body, thereby opening the valve and permitting a constantly smooth non-turbulent streamline flow. This occurs when the remote control valve is closed. By opening the small remote control valve, line pressure is diverted into the actuating chamber and establishes a pressure balance on the inner and outer walls of the expansible tube. The tube then "flexes" closed over the surface of the core. Static line pressure then maintains a positive bubble-tight, air-tight shutoff of the Flexflo valve, indefinitely. There is never the slightest possibility of sticking or freezing, it is stated.

The Flexflo valve employs no seats, disks, springs, or weights and has no packing gland, stuffingbox, or exposed members. In its compactness it requires no more head room than a pipe. Several Flexflo valves can be controlled from a central remote control station. This valve can be operated hydraulically or pneumatically by various systems such as manual, electro-solonoid, mechanical, or automatic remote control, it is asserted.

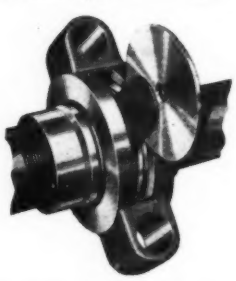
Full details in bulletin form are available on request. Ask for bulletin No. 800, Grove Regulator Company, 6569 Green Street, Oakland 8, California.

Line Blinds

A new bolted type line blind, especially designed for pipe line applications, and a new union type blind of very simple but rugged construction have been added to the equipment manufactured by the Hamer Oil Tool Company, Long Beach, California.

The bolted type blind, designated Model EW30, is available in sizes from 2½ to 12 in., of all-steel construction, and all flange nuts as well as the stud for spreading the flanges apart when changing the plate or spectacle are designed for turning with a straight bar. The plate or spectacle may be had with squeeze-type or pressure-seal packing retained in an annular groove in the plate, or it may be smooth for use with flat gaskets. Ends are threaded or beveled for welding, as preferred by the user.

MODEL BW30—All-Steel, Bolted Type Line Blind.



MODEL L150—All-Steel Union-Type Blind.

The union type blind is also made of steel, and is available in sizes ¾ in. and larger. It consists of two subs, which may be screwed or welded in the line, and a bar-operated nut slotted to receive the plate and flat gaskets. When the nut is turned to the left the faces of the subs are spread enough to release the plate. Turning the nut to the right draws the subs together so that the plate is tightly clamped between them and a positive seal is effected.

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PORUS-KROME *multiplies the life of* any *engine bore. Here are a few of the many types and sizes of cylinders and liners being processed by Van der Horst.*

* PORUS-KROME is hard chromium, applied by the Van der Horst process that produces pores to hold oil. It reduces wear, corrosion and scuffing, and greatly multiplies engine life when used on cylinder walls and other bearing surfaces.

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In producing this much PORUS-KROME, Van der Horst uses enough chromium in one month to chrome plate the hardware, bumpers and trim of more than 2,300,000 automobiles.

The acceptance of PORUS-KROME by the internal combustion engine industry is indicated by this current volume of production and the wide variety of type and size of engines now using PORUS-KROME on the cylinder bores.

PORUS-KROME is multiplying cylinder and ring life in engines in submarines, landing craft, destroyer escorts, ships, stationary and mobile power plants, trucks and buses, aircraft, and locomotives.

Results show that it multiplies cylinder life four to twenty times and reduces scuffing, scoring, ring feathering and risk of piston seizure.

Write for the booklet, "PORUS-KROME, good for the life of Your Engines."

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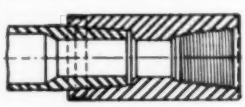
For fifteen years Tube-Borium has been used on drilling bits to increase cutting speeds and drill more out-to-gauge hole. Now you can use this same alloy to greatly prolong the life of your tool joints!

An exceedingly small quantity of Tube Borium welded in a ring around the shoulder not only doubles tool joint life—even under the toughest operating conditions—but maintains over all joint strength and correct elevator contour. Applications are economically made on both new and resleeved joints.

APPLICATION: Accepted method of application is to under-cut new or resleeved joints at the shoulder to form a recess 1/8" deep by 1½" wide. The recess is then filled by welding in with 3/16" Electric Tube Borium to form the wear resistant inlay.



Write for this special Stoody engineering bulletin describing in detail hard-facing procedures on tool joints—no obligation.

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Stellite-Tipped Tools

TWO new styles of tipped tools especially designed for machining steel have been announced by Haynes Stellite Company, a unit of Union Carbide and Carbon Corporation, Kokomo, Indiana. The new tools, designated as Style P and Style Q, consist of a cutting tip of Stellite 98M2 cobalt base alloy brazed or butt welded to a tough steel shank, with proper clearance and lead angles ground for turning steel. These and other Stellite tipped tools are for applications employing tools that have a large cross-section or tools that are bent or offset, or for tool holders that make the use of solid tool bits impractical. In addition to use in turning, boring, and facing operations, these tipped tools are also used for various types of forming and grooving operations.

Style P is a right-hand tool; Style Q is a left-hand tool. They are ground with a 15-deg. end cutting-edge angle, a 15-deg. side cutting-edge angle, a 7-deg. end relief angle, and a 7-deg. side relief angle. These tools have flat tops, so that users can grind their own side rake angle for each particular job. Five sizes of each tool are stocked, as follows:

⅜ by 1¼ by 8 in.
¾ by 1½ by 9 in.
1 by 1 by 7 in.
1 by 1¼ by 7 in.
1¼ by 1¼ by 7 in.

Style P and Q are also made with Stellite Star J-Metal tips.

Hard Boiled Hat

A COMPLETELY redesigned "Hard Boiled Hat," known as the "Airlined" model is now available from E. D. Bullard Company, San Francisco, California. Weight has been reduced to little more than 12 ounces, while impact resistance is increased through a new crown molding development.

FOR SALE—One Hope 4 Cyl. Vertical Gas Engine, 150 H.P., complete with Lubricators, Ignition System, etc. Directly connected to A-C 240 Volt, 180 Amp., 3 Phase, 60 Cycle Generator with completely equipped switchboard. Shunk Mfg. Company, Bucyrus, Ohio.

WANTED: Experienced Petroleum Engineers for work in South America. Give full particulars regarding experience, age, marital status, draft status. Applicant must comply with War Manpower regulations. Apply to Box 2, % The Petroleum Engineer, P. O. Box 1589, Dallas, Texas.

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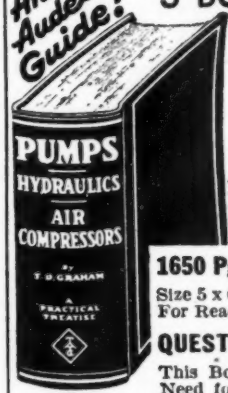

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Address_____
Occupation_____
Employed by_____ P.E.N.

Opens New Store

Republic Supply Company announces the opening of a new store at Kenedy, Texas, under the management of W. G. Jennings.

Personnel Shifts

The Marley Company, cooling tower manufacturers with main offices in Kansas City, Kansas, announces personnel shifts resulting from raising its Houston, Texas, office to the status of a divisional headquarters under the direction of Ray T. Jenkins, who formerly headed the Tulsa, Oklahoma, division.

The company is now represented in the Tulsa area (all of Oklahoma, western Arkansas, and the Texas panhandle) by Walter S. Smith and his Process Equipment Company, 306 Tulsa Building. Smith, a resident of Tulsa for more than 6 years, is well known throughout the territory as an applications engineer for heat transfer equipment.

From the main office, Joe T. McKinley has joined the Houston staff. The Kansas and western Missouri area is now handled by R. H. Ahrens out of the company's headquarters at Fairfax and Marley Roads, Kansas City, Kansas.

Heads Sand-Banum

The American Sand-Banum Company, Inc., of 9 Rockefeller Plaza, New York City, manufacturers of Sand-Banum boiler and engine scale and corrosion eliminants, announces the election of Louis Bradie to the office of president of the corporation to fill the vacancy created by the death of former president, George A. Kubler. Bradie has been secretary and treasurer of the corporation since it was founded by Kubler in January, 1926. He continues as treasurer.

Announcement is also made of the appointment of F. Fullgrabe, formerly assistant secretary, to the office of secretary.

The same progressive policies and high ideals established under the leadership of Kubler will be continued, it is announced.

Takes New Post

Alexander M. Hamilton was appointed vice president, foreign sales, of American Locomotive Company effective April 1.

A. M. HAMILTON

Between World War I and World War II Hamilton held various foreign sales positions with the company, serving as European representative with headquarters in Paris after the Armistice until 1921. He is presently executive vice president of Montreal Locomotive Works, Ltd., Canadian subsidiary of American Locomotive Company.

A graduate of Cornell in 1909 with the degree of Mechanical Engineer, Hamilton is a member of the Export Managers Club, and was president of the club from 1931 to 1933. He toured South America in 1941 as a member of the National Research Council.

Joins Elliott Company

The appointment of H. E. Miller, industrial engineer, to superintend new plant planning and layout and to direct the personnel department of the Springfield division of Elliott Company, is announced by G. L. Elliott, general manager of the plant.

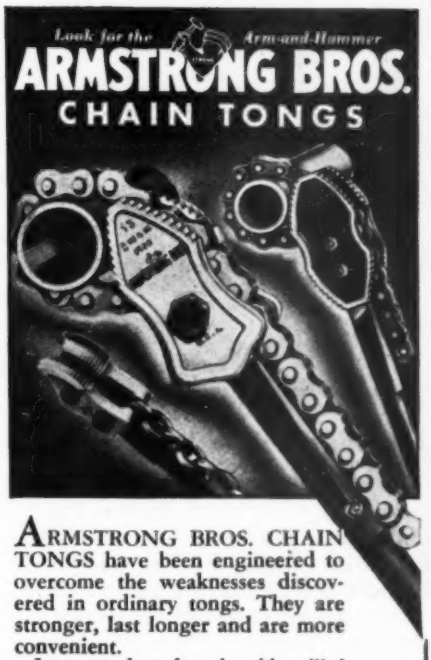
H. E. MILLER

Miller was born in Mercer County, Pennsylvania, and obtained his training in the shops of the Cooper-Bessemer Corporation.

Formerly associated with the National Supply Company of Springfield, he went to Elliott Company, Jeannette, Pennsylvania, where he was a senior industrial engineer and supervisor of standards, before his transfer to Elliott Company's Springfield division.

Major oil company has openings available for graduate petroleum engineers having at least 3 years' acceptable experience general oil field development. Salary open. All hiring will be done in accordance with W.M.C. Stabilization Plans. Reply to Box 3, % The Petroleum Engineer, P. O. Box 1589, Dallas, Texas.

WANTED: Construction superintendents and general foremen for general construction work. Must be familiar with all phases of construction in refineries and chemical plants. Should have some knowledge of operations. Give complete information, age, education, experience, ability, salary, availability, draft status. Replies confidential. Reply to Box 11, % The Petroleum Engineer, P. O. Box 1589, Dallas, Texas.



ARMSTRONG BROS. CHAIN TONGS have been engineered to overcome the weaknesses discovered in ordinary tongs. They are stronger, last longer and are more convenient.

Jaws are drop forged, with milled teeth, are heat-treated and extremely tough. They have inner lugs which increase the bearing on the bar and also prevent chains from jamming. Other strength features include forged handles, large hardened steel bolts, alloy steel shackles and proof-tested chains.

ARMSTRONG BROS. Tongs come in *all* standard types, each in *all* sizes.

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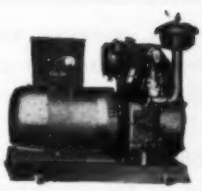

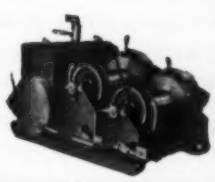

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Announce New Location

Perrault Brothers announce their new location at 1130 North Boston, Tulsa, Oklahoma. Formerly known as the Petroleum Coating Machine Company, Perrault Brothers supply line traveling combination coating and wrapping machines to the pipe line industry. In addition, they also have stationary, semi-portable yard type cleaning and priming, coating and wrapping machines.

Lewis and Ainslie Perrault entered the pipe line equipment and supply business in November, 1943, and acquired the services of Bo Bardsley, who has been in the pipe line equipment business for the last 30 years.

Sales Representatives

Kieley and Mueller, Inc., North Bergen, New Jersey, has announced the appointment of John C. Paster of Jacksonville, Florida, as exclusive sales representative in the entire state of Florida for the K & M line of automatic pressure and level control valves and equipment.

The appointment of W. E. Marmaud, 2852 East Grand Boulevard, Detroit 11, Michigan, as exclusive sales representative in Detroit and part of Michigan, also has been announced by A. E. Campbell, sales manager of Kieley and Mueller.

New Magazine Appears

The first issue of *Fasteners*, a publication of American Institute of Bolt, Nut, and Rivet Manufacturers, has been released, adding a valuable new record of information for business and industry.

Purpose of the magazine is to give greater service to the users of fasteners. The Institute has for years functioned as a clearing house for technical problems in connection with the application and use of headed and threaded products. Through the medium of *Fasteners* the results of technical research can be disseminated so that industry can avoid many difficulties and expedite manufacture by studying new data on fasteners.

An 8½ by 11-in. size for easy filing, the typography and format of the new magazine is outstanding even in this age of excellent printing. A multi-color cover, excellent photographs, and valuable articles make the first issue a distinguished volume. The articles are contributed by members of the Institute, which includes companies manufacturing bolts, nuts, screws, and other headed and threaded products.

A copy of *Fasteners* is obtainable from the American Institute of Bolt, Nut, and Rivet Manufacturers, 1550 Hanna Building, Cleveland 15, Ohio.

Organizes New Firm

Dr. Warren W. Leigh has resigned as special assistant to the deputy rubber director of the WPB to join Ralph C. Busbey in organizing the firm of Busbey and Leigh, management consultants, in Akron, Ohio. Dr. Leigh served with the WPB for more than a year, previously serving as price consultant and head of the tire price section of OPA. Before serving the government, he was head of the commerce department and professor of business administration of the University of Akron. Busbey is head of the Busbey Advertising Agency of Akron.

Busbey and Leigh will deal extensively with postwar planning for special clients, its services also embracing research, advertising, marketing, and business analysis. Offices are at 316 Water Street in Akron.

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Active Search for Oil Continues in South Dakota

☆ **With nine tests planned, 1944 is expected to be state's biggest year**

By Floyd Emerson

THE quest for oil in South Dakota, which was begun on a big scale 3 years ago, will be continued in 1944 with at least 9 test wells planned for this summer, according to John P. Gries, associate professor of geology at the South Dakota School of Mines and Technology at Rapid City. If the plans are carried out, 1944 will be the state's biggest oil exploratory year in history.

The first test of the year is expected to be spudded in soon near Gustave in Harding County by the Kerr-Lynn Company of Oklahoma City, Oklahoma, which is to drill the well under a unit agreement. Locations and drillers of the other 8 wells, which Gries says are planned, have not been announced.

The Gustave well is to be drilled in SE SE 32-15n-2e. The unit agreement combines the interests of several oil operators who have taken leases either from the federal government or other owners. Among them are Carter Oil Company, Northern Ordnance, Inc., A. I. Levorsen, Elma H. Levorsen, Fred G. Moser, Ada I. Moser, Norval Ballard, Everett Carr, and J. J. Deaner.

Northern Ordnance has been designated as the unit operator and will direct the drilling operations. The contract, it is reported, calls for a test of 8000 ft. The bulk of the leasing unit is in Butte County, south of the test site.

This year's prospective activity, spurred by the wartime need for oil, is a big increase over 1943 when drilling was limited to 2 major tests.

An 8000-ft. hole, drilled by Northern Ordnance of Minneapolis, Minnesota, under a farm-out agreement with the Carter Oil Company of Tulsa, Oklahoma, at SW SW 1-17n-1e, Harding County, was abandoned as dry.

Another hole drilled by the A. S. Woodward Company, Inc., of Denver, Colorado, a half mile north of Ardmore in Fall River County, SW SW 4-14s-4e, turned out to be a good natural gas well. The gas is to be sold to consumers in the town of Ardmore and the company has announced plans for drilling additional gas wells in the immediate vicinity.

The Ardmore well was drilled by the Woodward Company for the Jesse Roote interests of Denver.

The 8000-ft. Northern Ordnance well drilled last year was the deepest for South Dakota; however, it exceeded by only 20 ft. a 7980-ft. well drilled in the same vicinity by the Carter Company in 1940. The latter well found small shows of oil in the limestone formation and a considerable show in the Deadwood sandstone. Probable recovery of oil was not considered sufficient, however.

Failure of several tests in the state during the last 3 years does not seem to have dimmed the interest of a number of major oil companies. Substantial new leasing has been reported during the winter and a flurry of new leasing operations is expected this spring. Several million acres of land are now under lease in South Dakota and its sister state of North Dakota.

Recent leasing operations include leases on 30,000 acres of land in Fall River County by the Woodward Oil Company and Associates of Denver; on 3040 acres of Fall River County land by R. R. Wellington of Crawford, Nebraska, and on 1075 acres in Marshall County by Hugh H. Tobin of Langford, South Dakota.

Interest in western South Dakota was stimulated during the winter by the successful drilling of another well in the Newcastle, Wyoming, area, a few miles from the South Dakota line. The well, which was brought in by the Western Oil and Gas trust at 3852 ft., is expected to produce at least 1000 bbl. a day. Four more holes are being planned by the company in the Newcastle vicinity.

Although the present wave of interest in South Dakota oil prospects didn't get under way until about 3 years ago, oil tests have been made in the state intermittently since 1904. Fifty-six oil tests have been made in the state since then; however, only 21 of them were drilled as a result of surface mapping or geophysical studies, according to Gries.

Regulations to govern production of crude oil and gas in South Dakota by operating companies were adopted during the winter by the newly created State Oil and Gas Board.

Modeled after conservation regulations in other states the new rules are designed to prevent physical waste of oil or gas. They include requirements for drilling permits, notice to the board before abandonment of wells, plugging requirements, and preservation of logs.

A 10-acre spacing pattern has been established. Regulations of the PAW now require 40-acre spacing but the South Dakota board believes the federal regulations may be modified as more steel and tools become available for drilling operations.

New leasing terms have been established by the South Dakota rural credit board, which has thousands of acres of land under lease in the state. New leases are priced at 10 cents an acre for the first 5 years and 25 cents an acre for the next 5 years. Formerly the charges were 10 cents for the first 2 years and 10 cents a year for the remaining 8 years. The new scale conforms to that of the South Dakota school and public lands department leases. Both types of leases provide for ⅛ royalty to the state.

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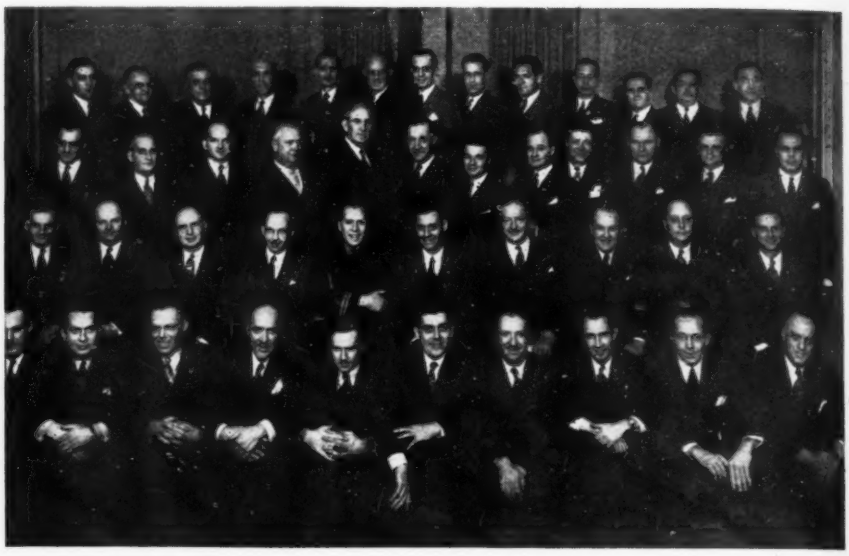
Representatives Meet

The annual meeting for the eastern representatives of the Pittsburgh Equitable Meter Company was held recently at the general offices of the firm in Pittsburgh, Pennsylvania.

Called in from their territories by Colonel W. F. Rockwell, president, the district managers and service engineers from Atlanta, Columbia, Brooklyn, Buffalo, New York, Pittsburgh, and Boston offices, met with company executives for a discussion of problems relating to field operations.



Those attending the conference: Front row—Maynard, Siedentopf, Obrock, Jerge, O'Grady, Atwell, Gottwald, Gavin, Ricketts, Abbott. Second row—Hamilton, Lufkin, Kenny, W. W. Dixon, Cloran, Jerman, Col. Rockwell, L. A. Dixon, Foster, Arens. Third row—Mowrey, Harper, Gordon, Eyler, Taylor, Moore, Stroyd, Thomas, Andrews, Smith, Rand, Marsh. Back row—McAulay, Brown, Keller, Noyes, Carlon, Oaks, Bixby, Geuss, Finley, Burnette, Fallows, Gleeson, Trimble.

Homco Honored

Houston Oil Field Material Company, Inc., was awarded the Army-Navy "E" flag April 3 in a colorful ceremony at the Company's Wayside Street factory in Houston for excellence in production of oleo shock struts for the Douglas C-47 Skytrain. It was the first such award made to a plant in this area for the manufacture of aircraft parts.

Major Robert K. Howse, procurement executive of the midwestern procurement district army air forces materiel command, presented the award to George O'Leary, president of the company, who in turn pledged a continuance of the company's outstanding efforts which won it. Lt. A. A. Nance, of the naval incentive division, presented "E" pins to Marvin H. Peck, who represented the men workers, and to Earline Priest, for the women.

President George O'Leary of Houston Oil Field Material Company, Inc., thanks the faithful workers of Homco who made possible the coveted Army-Navy "E" award on April 3, and the A.A.F. and Navy officials for recognition of the company's production performance.

Maxim Silencer Promotions

H. H. Maxim, president of the Maxim Silencer Company, has announced the appointments of Roland B. Bourne as vice president in charge of research, and Frank L. Orr as vice president in charge of sales for the company.

Bourne has directed the Maxim research department since 1925. Previous to coming into Maxim he was chief engineer of the C. D. Tuska Company, manufacturers of radio equipment.

Orr has been with the company since November, 1930, when he became district manager of the New York office. In 1935, when the sales department was moved from New York to Hartford, Orr became sales manager.

O. Smith Johannsen, has been appointed manager of the company's New York office, it is announced.

Riggers' Hand Book

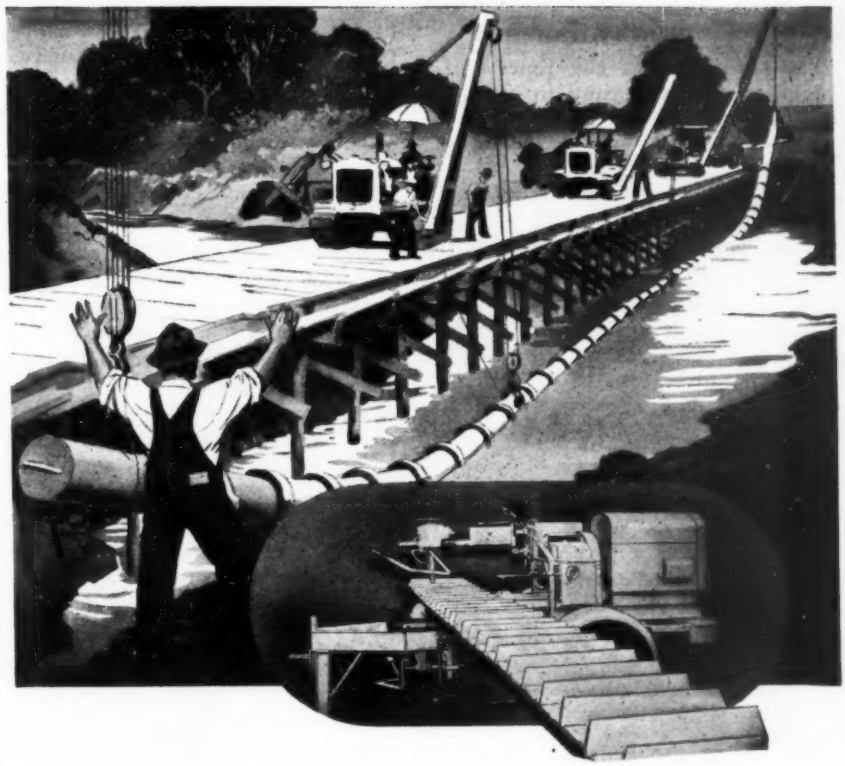
The Broderick and Bascom Rope Company has just issued a new edition of the "Riggers' Hand Book." Although it contains more pages than the previous issue it is unnecessary to dig through a big collection of words to get helpful information—it is mostly pictures and practical tables.

When to choose the different types of slings, what the working loads are, where to look for wear, how to measure are a few of the fundamentals helpfully reviewed. In the section of the book devoted to Yellow Strand braided safety slings it shows how their flexibility simplifies handling awkward, slippery, or odd-shaped loads. The patented braiding of this non-kinking type permits a soft, sure-gripping sling without surplus weight or bulk.

The book is small enough to fit into a pocket and a copy may be had by sending a request on company letterhead to Broderick and Bascom Rope Company, 4203 North Union Boulevard, St. Louis 15, Missouri.

The company also has an 80-page "Drillers' Hand Book" that will be sent on request to drillers, or anyone using or buying wire rope.

WANTED: A Petroleum Engineer with field experience, for engineering development work, with a large manufacturer of oil field equipment and materials. Permanent position with good future for right man. In reply state age, education, business background, salary desired, etc. Address Box 5, % The Petroleum Engineer, P. O. Box 1589, Dallas, Texas.



Pipe Lines Can't Wait!

NEITHER in peace nor in war can pipe lines wait. They must go through with dispatch and in spite of Nature's obstacles. Service of tractors and buldozers, on the job night and day to clear the way, must not be delayed a single needless instant.

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Rodgers HYDRAULIC Inc.

Supply Company Formed

The formation of the Jones and Laughlin Supply Company to succeed Frick-Reid Supply Corporation, a wholly owned Jones and Laughlin Steel Corporation subsidiary, was announced by H. E. Lewis, president of the steel corporation. The change in name was made to identify more clearly the supply company's activities and its relationship to the corporation. The principal office of the new company will remain at Tulsa, Oklahoma.

J. L. SHAKELY

The new company is exclusive distributor of Jones and Laughlin oil country tubular products east of the Rocky Mountains.

J. L. Shakely, who has been with Frick-Reid more than 30 years, and president since 1938, has been elected president of the new company. Other officers, including Robert McCoy, Jr., executive vice president; H. H. Wilson, vice president, and P. R. Warner, treasurer, also have been elected to serve in identical capacities with the new company.

Reappointments in the new company organization include R. P. Mase, chief engineer; N. C. Turner, assistant chief engineer; S. A. Whitehurst, manager of sales; V. C. Canter, general superintendent; L. G. Sutter, assistant general superintendent, all of the engineering and construction division, and Rainey Elliott, sales manager of general supplies.

R. J. Woods will be manager of tube sales of the supply company in the Mid-Continent area, with headquarters in Tulsa. Woods was formerly district sales manager for Jones and Laughlin Steel Corporation in Tulsa and has been succeeded by J. H. Tice.

Henry J. McAdams, formerly with the steel corporation in New York City, has been appointed manager of Jones and Laughlin Supply Company, New York office.

H. E. Wagner, district sales manager of the eastern oil and gas fields for the supply company, is being transferred from headquarters at Bradford, Pennsylvania, to the supply company's offices at 311 Ross Street, Pittsburgh, Pennsylvania. J. K. Lytle continues in the capacity of assistant to Wagner.

The Houston office will continue under the direct supervision of H. H. Wilson, vice president, with T. L. (Dick) Lewis, who recently joined the organization, as district manager of tube sales. They will be assisted by C. B. Moore, city sales manager; G. S. Emerson, salesman; G. E. Tyson, salesman, and J. T. Batchelor, chief clerk.

F. D. Winslow, district sales manager for Jones and Laughlin Steel Corporation in Houston, Texas, continues in that capacity, having charge of the sale of all steel products other than oil country tubular goods.

Opens Magnolia Store

Bethlehem Supply Company is opening a new store at Magnolia, Arkansas. W. A. Meagher will be store manager and field representative.

This store area comes under the general supervision of Fred Parks, district manager, Dallas, Texas.

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Put 'em in the heaviest, most powerful equipment built . . . subject 'em to the most abusive, gruelling punishment you can think of—and AMERICAN HEAVY DUTY ROLLER BEARINGS will render smooth, flawless, efficient, continuous, trouble-free service for maximum periods with minimum maintenance requirements.

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FORMER ENGINEERING STUDENTS—Major oil company desires applications of persons who are interested in getting into the petroleum industry and who have been engineering or geological students in a reputable school or university. Experience helpful, but not essential. Do not apply if employed in essential activity at highest skill. Address Box 6, % The Petroleum Engineer, P. O. Box 1589, Dallas, Texas.

Koberg With BJ

The oil tool division of Byron Jackson Company, Los Angeles, California, announces the appointment of E. R. (Ed) Koberg as BJ oil tool service engineer at Baton Rouge, Louisiana, to cover Louisiana, Mississippi, Arkansas, and eastern Gulf Coast fields.

Koberg attended the University of Buffalo, and later graduated as a mechanical engineer at Louisiana State University. He was associated for several years with the National Supply Company and Murray Brooks Hardware Company.

Joins W. C. Norris

R. B. Stanbery, widely experienced in the application of subsurface equipment in the Mid-Continent and the Pacific Coast areas, has become associated with W. C. Norris, Manufacturer, Inc., Tulsa, Oklahoma, as Mid-Continent sales and service representative.

R. B. STANBERY

Stanbery gained his first oil field experience with the old Frick and Lindsay Company, later the Frick-Reid Supply Corporation. In 1927 he moved to California where he was employed by Superior Oil Company of California. While in the area he also worked for Emsco Derrick and Equipment Company but in 1935 moved to Dallas where he entered the employ of Continental Supply Company.

His time will be devoted to the development of sales and service in the sucker rod division.

Acquires Stock Interests

Byron Jackson Company has acquired the interest in International Cementers, Inc., formerly owned by Schlumberger Well Surveying Corporation. The interests of Dowell Incorporated, and Baker Oil Tools, Inc., remain unchanged. The corporate offices have been moved from Houston, Texas, to Los Angeles.

E. S. Dulin, of Byron Jackson Company, succeeds E. G. Leonardon of Schlumberger Well Surveying Corporation as president of International Cementers. Other officers are: J. D. Chesnut, executive vice president; N. R. Crawford, vice president and treasurer; R. Henquet, vice president; C. Penhaligen, auditor, and W. H. Wiese, secretary and assistant treasurer. The operating personnel, with Ward B. Tennis acting as general manager, remains unchanged.

Directors are A. P. Beutel, J. D. Chesnut, N. R. Crawford, E. S. Dulin, Donald Y. Lamont, F. C. Merritt, C. Penhaligen and T. Sutter.

Spalding Promoted

John D. Spalding has been named works manager of the Superior Engine Division plant of The National Supply Company at Springfield, Ohio. He has been works manager at the Torrance, California, plant.

J. D. SPALDING

Educated at Carnegie Institute of Technology in mechanical engineering and Duquesne University Law School, Spalding joined the National organization as plant engineer at Carnegie, Pennsylvania, plant in 1923.

The $64 Question

What is likely to make any well more profitable and satisfactory when it has to be pumped?

Hundreds of successful producers from coast to coast and Gulf to Great Lakes will tell you promptly: A JENSEN PUMPING UNIT.

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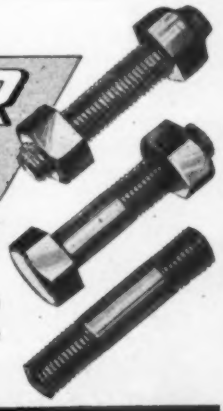

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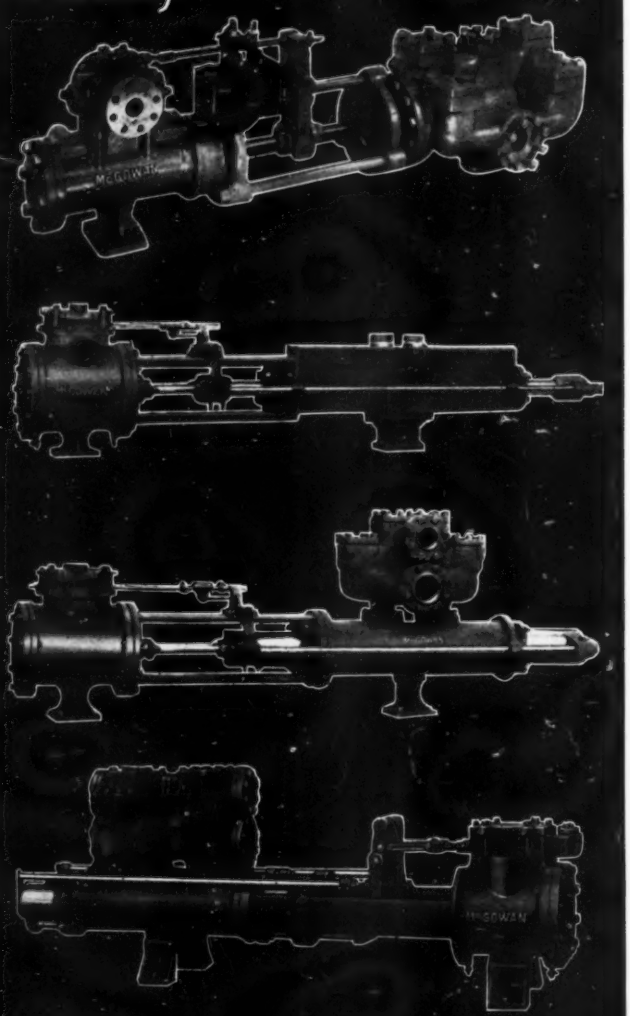

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BJ Transfers Pugh

D. O. Pugh, sales and service engineer for the oil tool division of Byron Jackson Company, Los Angeles, California, recently has transferred his headquarters to Tulsa, Oklahoma. In addition to contacting the Tulsa offices of various companies, Pugh will make regular trips to cover the Kansas, Oklahoma, and North Central Texas areas.

New President Fluor Corporation

P. E. Fluor, formerly vice president and general manager of The Fluor Corporation, Ltd., Los Angeles, California, has been elected to the presidency of that company. Other executive changes include the election of J. S. Fluor, Jr., to the office of vice president and general manager, and Milton Lewis to the office of assistant general manager. Lewis also was elected to serve as a member of the board of directors.

Meter Company Elects Officials

At the annual meeting of the Pittsburgh Equitable Meter Company, Colonel Willard F. Rockwell was elected chairman of the board. Colonel Rockwell, who has been president of the company since 1926, will continue as active head of the firm

E. W. MEYERS

W. S. POTTER

and serve in the dual capacity of president and board chairman.

Subsequently announced were the elections of Edgar W. Meyers as director and William S. Potter as vice president.

Meyers, treasurer for the last 18 years, will continue to serve in that position.

Potter formerly was assistant works manager. He has been connected with the Pittsburgh concern for 14 years in various engineering and production capacities.

Joins A. O. Smith Corporation

In accepting the appointment of industrial consultant, Frederick E. Moskovics brings to the A. O. Smith Corporation of Milwaukee, Wisconsin, a background of diversified, practical experience in organizing the production of vital war materiel.

F. E. MOSKOVICS

For the last 3 years Moskovics was technical advisor to the supervisor, Army Air Forces, where his cooperation with industry was one of the major factors in this country's phenomenal plane production. His industrial knowledge, based on more than 40 years' technical experience in industry, was valuable in solving many of the bottlenecks that hampered progress in the first few months after Pearl Harbor.

TRADE LITERATURE

What to Write For

LITERATURE ON EACH of the following tools will be sent promptly upon request to Grant Oil Tool Company, 2042 East Vernon Avenue, Los Angeles 11, California: Bailers, cleaners, hole enlargers, liner pullers, reamers, shale bits, underreamers, and wall scrapers. Specify the tool or tools in which you are interested.

"HYDRAULIC TORQUE CONVERTERS," their function, operation, and installation, are concisely presented in a 16-page booklet published by the Twin Disc Clutch Company, Hydraulic Division, Rockford, Illinois, and available upon request. A clear understanding can be gained from the booklet of the capabilities of this modern method of obtaining mechanical advantage between driving and driven units.

A 52-PAGE BOOKLET replete with facts is "Lane-Wells Radioactivity Well Logging." The nature of radioactivity and the applications of the logging service to the problems of the petroleum industry are discussed. Typical curves and sections are reproduced from nearly all the principal oil field areas in the United States. Copies are available to oil company executives, petroleum engineers, geologists, and field superintendents from Lane-Wells Company, 5610 South Soto Street, Los Angeles 11, California, or the nearest division office.

AN INTERESTING BOOKLET on the S-A type boiler has been issued by Foster Wheeler Corporation, which will send copies when addressed at 165 Broadway, New York 6, New York, Department "M." The 28-page pamphlet contains drawings and photographs and operating data at a number of well known plants. A large simplified chart gives heat content of steam.

WAILES DOVE-HERMISTON CORPORATION has released two new folders on Bitumastic protective coatings for industry. "Bitumastic Visual Index" gives a complete chart showing use of coating in a plant. The other one, "Bitumastic Blacks," describes these types of coatings and their protective uses.

FLEXIBLE SHAFT COUPLINGS are described in the revised edition of Bulletin No. 12 by the Diamond Chain and Manufacturing Company, Indianapolis 7, Indiana. The advantages of this type of Diamond roller chain couplings are explained and many applications shown. Dimensions and hp. rating as well as enclosed casing dimensions and weights are given.

New Officers

Officers for each organization were elected following the joint meeting in Dallas, Texas, of the Society of Exploration Geophysicists and of the American Association of Petroleum Geologists.

Dr. W. M. Rust, Jr., Humble Oil and Refining Company, Houston, Texas, is the new president of the geophysicists. Other officers are Henry C. Cortes, Magnolia Petroleum Company, Dallas, vice president, and W. Harlan Taylor, Petty Geophysical Engineering Company, San Antonio, secretary-treasurer. J. A. Sharpe, Stanolind Oil and Gas Company, Tulsa, Oklahoma, continues as editor.

The geologists' new president is Ira H. Cram, Pure Oil Company, Chicago, Illinois. Warren B. Weeks, Phillips Petroleum Company, Shreveport, Louisiana, was elected vice president, and Robert E. Rettger, Sun Oil Company, Dallas, was re-elected secretary-treasurer. Professor Gayle Scott, Texas Christian University, Fort Worth, Texas, was chosen editor.

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New Dow Office

The Dow Chemical Company opened a new office in Detroit on April 1, Leland I. Doan, vice president and general sales manager of the concern, announced.

The third new Dow office to be opened within three months, the move will bring the total of such offices throughout the country to 12.

Walter J. Truettner, who has been well known in Detroit business for the last 17 years, heads the new office. Truettner has been actively associated with the Dow Magnesium Corporation since February, 1942. He has resigned his position as secretary of the Marysville plant to take over his new duties.

Ralph B. Ehlers, who has been with Dow for the last 8 years and assistant chief engineer of Dow Magnesium Corporation since 1942, will be located at the new office in charge of magnesium distribution and service in southeastern Michigan. Other members of the Detroit office will be Paul M. Jensen, in charge of plastics, and Fielding H. Yost, Jr., in charge of industrial chemicals and pharmaceuticals.

Creagh Promoted

Edward V. Creagh has been appointed advertising and sales promotion manager of American Chain and Cable Company, Inc., and Associate Companies, Bridgeport, Connecticut.

Creagh joined the company in 1916, and his service has been continuous, except during World War I, when he was in the army. He has been in charge of sales promotion activities since 1936. Hs new duties will cover newspaper, magazine, business publications, and other forms of advertising, in addition to sales promotion.

One of the organizers and first president of the western New England chapter of National Industrial Advertisers Association, Creagh is now serving as a vice president of the National organization.

Awarded Army-Navy "E"

Displaying the "E" flag to 1000 employees are left to right: Admiral Cluverius, President W. T. Morris, G. C. Gregson, manager of plants, Maj. Howard P. Klair and Patrick Shovlin

The efficiency and excellence of production of the Wilkes-Barre, Pennsylvania, plant of Hazard Wire Rope and American Cable Divisions of American Chain and Cable Company, Inc., were honored by the army and navy when nearly 1000 employees were awarded the Army-Navy "E." Presentation of the award was made by Rear Admiral Wat T. Cluverius and it was accepted by George C. Gregson, manager of plants. The "E" Pins were presented by Maj. Howard P. Klair.

MEETINGS

Petroleum Industry Electrical Association and the Petroleum Electric Supply Association—Last week in April, Dallas, Texas.

California Natural Gasoline Association, Monthly Meeting—May 4, Rio Hondo Golf Club, Downey, California.

American Institute of Mining and Metallurgical Engineers, Petroleum Division—May 8, 9, and 10, Rice Hotel, Houston, Texas.

American Society of Mechanical Engineers Oil and Gas Power Division, Annual Meeting—May 8, 9, and 10, Mayo Hotel, Tulsa, Oklahoma.

American Gas Association, Natural Gas Department—May 11, 12, and 13, French Lick Springs Hotel, French Lick, Indiana.

American Petroleum Institute, Mid-Continent District, Division of Production—May 25 and 26, Mayo Hotel, Tulsa, Oklahoma.

Southwestern Gas Measurement Short Course—June 6, 7, and 8, Norman, Oklahoma.

American Petroleum Institute, Southwestern District, Division of Production—June 13 and 14, Rice Hotel, Houston, Texas.

American Society for Testing Materials, Annual Meeting—June 26, 27, 28, 29, and 30, Waldorf-Astoria Hotel, New York, N. Y.

American Society of Mechanical Engineers, Fall Meeting—October 2, 3, 4, and 5, Cincinnati, Ohio.

Texas Mid-Continent Oil and Gas Association, Annual Meeting—October 12 and 13, Rice Hotel, Houston, Texas.

American Petroleum Institute, Annual Meeting—November 13 ,14, 15, and 16, Stevens Hotel, Chicago, Illinois.

American Association of Oilwell Drilling Contractors, 1944 Meeting—Fort Worth, Texas, date to be announced.

Hanlon-Waters Awarded Army-Navy "E"

At an impressive ceremony held at the company plant in Tulsa, Oklahoma, Hanlon-Waters, Inc., builders of the equipment for the army's famed portable pipe line, were presented with the Army-Navy "E" award for excellence in production.

The award program was held in the company's recently completed new building, which will house the final assembly and crating departments. Col. H. A. Montgomery, executive officer, Supply Division, Office of the Chief of Engineers, in making the award stated that the pumping units manufactured in the Hanlon-Waters plant are being used by our armed forces and those of the Allies "in every theatre of operations throughout the world." Capt. E. L. Woodside, commanding officer, Naval Ammunition Depot, McAlester, Oklahoma, also praised the company.

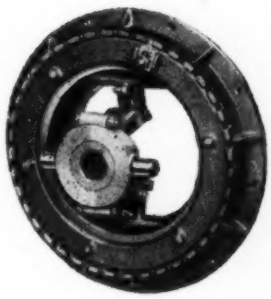
President M. F. Waters received the award on behalf of his company.

Correction

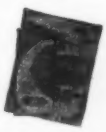
A typographical error was made in the article by W. G. Taylor, "Resources Conserved by 'Big Inch' Line," which appeared in the March issue of *The Petroleum Engineer*. On page 120, first column, under "Operating Costs," in the eighth line of that paragraph it states, $2.34 per one hundred gross ton-miles." The correct figure is $2.34 per one thousand gross ton-miles.

How ROCKFORD CLUTCH Design Decreases Inertia in Driven Parts

Gear shifting or quick braking of the driven shaft is made easier through the use of ROCKFORD Over Center CLUTCHES by mounting the lighter part on the driven shaft. This faced clutch plate is of strong, light-weight construction — which promotes accurate balance and decreases *inertia of motion.* Can be assembled with an oil deflector and has a forged steel, multi-splined hub. Let our engineers show you how this and other ROCKFORD Over Center CLUTCH advantages will benefit your new and improved products.



SEND FOR THESE HANDY BULLETINS ON POWER TRANSMISSION CONTROL



They tell and show how ROCKFORD CLUTCH and POWER TAKE-OFF applications are saving time, power and money in oil field equipment and a wide variety of industries. Give capacities, dimensions and specifications.

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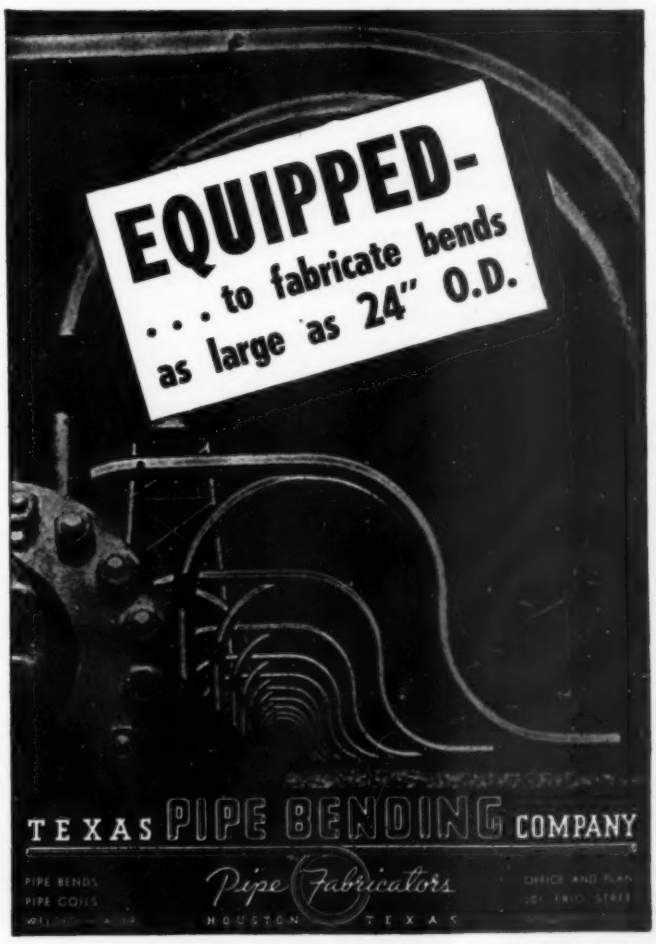


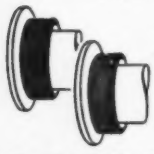
STOODY SELF-HARDENING MAKES THE DIFFERENCE!

ABOVE are two reclaimed rollers taken from the same tractor. The upper roller was rebuilt to size with high carbon electrodes alone, but the lower roller carried a protective layer of Stoody Self-Hardening over the high carbon build-up*.

Abrasive conditions encountered in tractor operation were so severe the top roller was worn out in three months' time. The Stoody Self-Hardening, however, kept the lower roller in operation for another three-months period, a life increase of 100%!

Cost of the Stoody Self-Hardening deposit can be ignored, considering benefits obtained and the time saved in eliminating an extra overhaul.

Hard-facing can be applied either of two ways: (1) A bead run around the outer edge and space between the bead and collar filled in with horizontal welds or (2) A bead around the outer edge to bring the roller back to diameter, and intervening area between outer edge and collar filled with a continuous spiral of hard metal. Either method is equally successful but the latter has the advantage of more easily maintaining roller concentricity.



Have you received your copy of Stoody Specification Sheets? They illustrate and describe dozens of equipment-saving applications thru the use of hard-facing—sent free on request.

*The preliminary high carbon build-up can be eliminated if Stoody Self-Hardening is applied before excessive wear has occurred on the roller.

STOODY COMPANY
1142 W. SLAUSON, WHITTIER, CALIF.

STOODY HARD-FACING ALLOYS
Stop wear . . . Eliminate Repair

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